Université de Montréal

# Follow-up of three large community-based programs to reduce anaemia among children 24-59 months in Ghana, Malawi and Tanzania

par
Kendra Warkentin

Département de Nutrition
Faculté de Médecine

Thèse présentée à la Faculté de Médecine
en vue de l'obtention du grade de Ph.D.
en Nutrition

March 2011

Université de Montréal
Faculté de Médecin

Cette thèse intitulé(e) :

Follow-up of three large community-based programs to reduce anaemia among children 24-59 months in Ghana, Malawi and Tanzania

présentée par :
Kendra Warkentin

a été évaluée par un jury composé des personnes suivantes :

Bryna Shatenstein
président-rapporteur

Olivier Receveur
directeur de recherche

Slim Haddad
codirecteur

Geetanjali Datta
membre du jury

Erick Boy-Gallego
examinateur externe

Kannan Krishnan
représentant du doyen

# Abstract

Childhood anaemia remains a problem of global health importance, despite decades of research to understand its aetiology and develop effective interventions to reduce its prevalence and consequences. While the individual risk factors for anaemia in young children are known, including factors related to undernutrition and morbidity, much less is known about the interaction amongst these in contexts where children are frequently exposed to several at the same time. This study seeks to document the anaemia control efforts of the Micronutrient and Health (MICAH) program implemented in Ghana, Malawi and Tanzania and use both process and evaluation data collected during the program to better understand the risk factors for anaemia in young children in these contexts and how these risk relationships may have changed over time during the intervention. Specifically, this study tests whether there is evidence of a reduction in child vulnerability to the risk factors associated with anaemia in each context.

A review of program documentation was conducted to characterize the program contexts and interventions, including estimates of intensity and reach. Cross-sectional data on the nutrition and health status of children 24-59 mo (N=2405) obtained in 2000 and 2004 from community-based program evaluation surveys in Ghana, Malawi and Tanzania, were used to describe the prevalence of anaemia. Multinomial logistic and linear regression models were used to estimate the risk of mild and moderate/severe anaemia and low haemoglobin, respectively, associated with groups of variables. Population attributable risk (PAR) estimates were also calculated.

Anaemia (haemoglobin <110 g/L) affected at least 60% of children in all three countries; moderate/severe anaemia (<100 g/L) accounted for the majority of cases. A large decrease in anaemia was observed between 2000 and 2004 in Ghana, but only a small decrease in Malawi and Tanzania. The risk of moderate/severe anaemia was associated with stunting in children from Ghana (OR 2.68; 95% CI 1.70, 4.23) and Malawi (OR 1.71; 1.29, 2.27) but not Tanzania (OR 1.29; 0.87, 1.92). Malaria and recent illness was associated with lower Hb overall; attenuation of this association in

2004 was observed only in Malawi for malaria and Ghana for illness. Children 48-59 mo were at least 44% less likely than those 24-35 mo to have moderate/severe anaemia in all three countries and this did not change between 2000 and 2004. PAR estimates showed that roughly one fifth of moderate/severe anaemia cases were attributable to stunting in Ghana and Malawi but not Tanzania. Lower and context-variable PAR estimates were found for malaria and recent illness.

Integrated health and nutrition interventions altered the relationship of some but not all risk factors for anaemia. Stunting remained an independent and non-buffered risk factor for anaemia. Effectively reducing the causes of chronic undernutrition is required in order to reduce child vulnerability and ensure maximum impact of anaemia control programs. Some buffering of malaria impact may be achieved in endemic settings.

**Keywords**: anaemia, haemoglobin, undernutrition, stunting, malaria, preschool children, vulnerability, Africa

# Résumé

L'anémie de l'enfant reste un problème d'importance pour la santé mondiale, malgré les décennies de recherche visant à comprendre son étiologie et à développer des interventions efficaces pour réduire sa prévalence et ses conséquences. Bien que les facteurs de risque individuels de l'anémie soient connus, y compris les facteurs liés à la malnutrition et à la morbidité, l'interaction entre lesdits facteurs est moins documentée dans des contextes où les enfants sont fréquemment exposés à plusieurs facteurs en même temps. Cette étude vise à documenter les efforts de lutte contre l'anémie du programme MICAH qui a été mis en œuvre au Ghana, au Malawi et en Tanzanie. Ensuite, en utilisant les données relatives à la fois au processus et à l'évaluation colligées au cours du programme, elle vise à mieux comprendre les facteurs de risque d'anémie chez les jeunes enfants dans ces contextes et à comprendre comment les relations entre ces facteurs peuvent avoir changé au fil du temps lors de l'intervention. Spécifiquement, cette étude vérifie s'il y a des preuves d'une réduction de la vulnérabilité des enfants aux facteurs de risque associés à l'anémie dans chaque contexte.

Un examen de la documentation a été réalisé afin de caractériser le contexte du programme et des interventions, leur l'intensité et étendue. Les données transversales sur la nutrition et l'état de santé des enfants âgés de 24 à 59 mois (N = 2405) obtenues en 2000 et 2004 à partir des enquêtes d'évaluation du programme MICAH au Ghana, au Malawi et en Tanzanie, ont été utilisées pour décrire la prévalence de l'anémie. Les modèles polynomiaux de régression logistique et linéaire ont été utilisés pour estimer les risques d'anémie légère et d'anémie modérée / sévère et les niveaux d'hémoglobine associés à des groupes de variables. Les estimations du risque attribuable à une population (RAP) ont aussi été calculées.

Une anémie (Hb <110 g/L) a touché au moins 60% des enfants dans les trois pays; l'anémie modérée / sévère (<100 g/L) constituait la majorité des cas. Une forte diminution de l'anémie a été observée entre 2000 et 2004 au Ghana, mais seulement une légère baisse au Malawi et en Tanzanie. Le risque d'anémie modérée / sévère était associé au retard de croissance chez les enfants du Ghana (OR 2,68, IC 95% 1,70-4,23) et du Malawi (OR 1,71; 1,29-2,27) mais pas de la Tanzanie (OR 1,29; 0,87- 1,92). Le

paludisme et les maladies récentes étaient associées à une hémoglobine plus basse. Une atténuation de cette association en 2004 a été observée seulement au Malawi pour le paludisme et au Ghana pour les maladies récentes. Le risque d'anémie modérée / sévère était 44% moindre chez les enfants âgés de 48 à 59 mois comparativement aux enfants de 24 à 35 mois dans les trois pays et cela n'a pas changé entre 2000 et 2004. Les RAP estimés ont montré qu'environ un cinquième des cas d'anémie modérée à sévère était attribuable au retard de croissance au Ghana et Malawi, mais pas en Tanzanie. Des RAP moindres et dépendants des contextes ont été trouvés pour le paludisme et les maladies récentes.

Dans ces zones d'intervention intégrées de santé et de nutrition la relation de certains facteurs de risque à l'anémie se modifia avec le temps. Le retard de croissance est resté toutefois un facteur de risque indépendant et non mitigé de l'anémie. Une réduction efficace des causes de la malnutrition chronique est nécessaire afin de réduire la vulnérabilité des enfants et de garantir un impact maximum des programmes de lutte contre l'anémie. Une mitigation de l'impact du paludisme peut par contre être visée dans les régions endémiques.

**Mots clés** : anémie, hémoglobine, malnutrition, retard de croissance, paludisme, enfants préscolaires, vulnérabilité, Afrique.

# Table of Contents

# List of Tables

# List of Figures

# List of acronyms and abbreviations

| | |
|---|---|
| ACT | Artemisinin-based combination therapy |
| ADP | Area development programme |
| ANC | Antenatal care |
| ANOVA | Analysis of variance |
| ARI | Acute respiratory infection |
| ASF | Animal source foods |
| BCG | Bacillus Calmette Guerin |
| CHV | Community health volunteer |
| CI | Confidence interval |
| DALY | Disability adjusted life year |
| DHS | Demographic and health survey |
| DPT | Diptheria Pertussis Tetanus |
| EPP | Erythrocyte protoporphyrin |
| GLM | General linear model |
| HAZ | Height-for-age z-score |
| Hb | Haemoglobin |
| HIV | Human immunodeficiency virus |
| HKI | Helen Keller International |
| IDA | Iron deficiency anaemia |
| IFA | Iron and folic acid supplements |
| IMCI | Integrated Management of Childhood Illness |
| IPT | Intermittent preventive treatment |
| IRS | Indoor residual spraying |
| ITN | Insecticide treated net |
| MCA | Multiple correspondence analysis |
| MCV | Mean cell volume |
| MICAH | Micronutrient and health |
| MMN | Multiple micronutrient |
| MOA | Ministry of Agriculture |
| MOH | Ministry of Health |
| NGO | Non-government organization |

| | |
|---|---|
| OPV | Oral polio vaccine |
| OR | Odds ratio |
| PAR | Population attributable risk |
| PCA | Principal components analysis |
| RCT | Randomized controlled trial |
| RNI | Recommended nutrient intake |
| SD | Standard deviation |
| U5 | Under five years of age |
| UNICEF | United Nations International Children's Fund |
| WAZ | Weight-for-age z-score |
| WHO | World Health Organization |
| WHZ | Weight-for-height z-score |
| WV | World Vision |
| ZPP | Zinc protoporphyrin |

*I dedicate this work to Irena Siekmans*
*(1946-2010)*

*"Now we see but a poor reflection as in a mirror; then we shall see face to face. Now I know in part; then I shall know fully, even as I am fully known."*
*I Corinthians 13:12, The Bible*

# Acknowledgements

With deep, heartfelt gratitude to all who have been a part of this journey:

To the Creator of the universe, the God of all knowledge and truth. May this work honour you.

To John for believing in me always…

To Prof. Olivier Receveur, for being an incredibly wise and patient director. From our first conversations in Ghana where this journey began until today, it is truly an honour to learn from you. You saw what I could not see and helped me to stay grounded. And you were right – this thesis will not change the world. But it has provided such a valuable space for learning and growing, something for which I will always be grateful to you.

To Prof. Slim Haddad, for calling everything into question and, in the end, helping me finally "get it". Your passion and logic are inspiring and I am grateful for the time you have spent with me, helping to define and refine.

To the Nutrition Department at UdeM for graciously accepting me as a non-traditional student, patiently bearing with my "mauvais francais" and supporting my research through bursaries. A special thanks to Karim Mourou, Victor Mirindi, Ying Zhang, Charles Dabone and others who shared with me not only the students' office but also their individual journeys of life and learning.

To my World Vision colleagues, with whom I began my professional career in international nutrition and who encouraged me to go further in my studies. I want to thank Carolyn MacDonald, in particular, for believing in me in the beginning, giving me such broad opportunities to grow professionally and mentoring me along the way. Thank you to the members of the Nutrition Team who were such a joy to work with and who have cheered me on the whole way. For inspiration and incredible opportunities to learn from committed individuals "on the ground", I sincerely express my gratitude to Banda Ndiaye, Mike Neequaye, Raymond Owusu, Anatoli Rugaimukamu, Gideon Muganda, Rose Namarika, Miriam Yiannakis, Zewdie Wolde-Gebriel and many others. I am also grateful to Alexander Kalimbira for sharing his Malawi data sets with me.

To my parents who are proud of me no matter what. To the rest of my family who may not always have understood what I was doing and why writing a thesis would take so long, but who made a constant effort to love and support me anyways.

To Minerva Rudman who is the sunshine in my day and best friend extraordinaire. To Alain and Dara Goulet for being my home away from home. To Jim and Naomi Klaas who listened so patiently and helped me to find perspective in the most difficult times. To Peter Berti for helping me see things differently, whether through creative graphs, insightful feedback or quips that made me smile. To Barry Dueck for that insightful chat about rates of change and the importance of terminology.

To the children, families and communities who continue to inspire and motivate me.

*Acknowledgement of funding*

The MICAH program was funded by the Canadian International Development Agency and World Vision Canada.

# CHAPTER 1: INTRODUCTION

# 1 Introduction

Childhood anaemia is a public health concern in every society of the world, but its highest prevalence among preschool children is observed in sub-Saharan African countries. The negative consequences of anaemia during the first few years of life are related, in large part, to its aetiology, whether iron deficiency, malaria or other causes, and the period of development in which anaemia is experienced. Nonetheless, the short-term and long-term effects of anaemia on child growth, development and survival are sobering and provide the impetus for international action to address it. Following decades of research, much is known about the specific causes of anaemia in various regions of the world, including nutritional deficiencies of iron and other micronutrients, malaria and helminth infections, inflammation, human immunodeficiency virus (HIV) and genetic haemoglobinopathies. However, much less is known about the interaction, whether additive, synergistic or antagonistic, amongst these various causes in contexts where young children are frequently exposed to several of them at the same time. In particular, the contribution of coexisting undernutrition, as evidenced by the high levels of stunting in these same contexts, has not been well-characterized.

Furthermore, research has traditionally focused on the biological aspects of anaemia in the individual, with less consideration of the social, economic and ecologic factors that underlie all aspects of child health and nutritional status. As a result, the development and testing of interventions to reduce child anaemia have tended to focus on technological advances that target specific nutrient deficiencies or diseases. There is no doubt that the complexity of anaemia in early childhood in malaria-endemic settings has been a major barrier to finding an adequate response. In the past decade, there have been diligent efforts to design programs with multiple, integrated nutrition and health interventions that are specifically targeted toward children during critical periods of vulnerability. Yet the evidence base for the effectiveness of these efforts is still very small and solid program evaluations of integrated program effects on anaemia in children are limited, both in scale and number.

This study seeks to document the anaemia control efforts of the Micronutrient and Health (MICAH) program implemented in several African countries and use both process and evaluation data collected during the program in Ghana, Malawi and Tanzania to better understand the risk factors for anaemia in young children in these contexts and how these risk relationships may have changed over time during the intervention. The theoretical framework guiding this work depicts the various causes of anaemia in a multi-level manner, with undernutrition and morbidity as the immediate causes of anaemia, household food security, child care practices, access to health services and healthy environments as underlying causes, and human, economic and organizational resources as basic causes.

The perspective taken in this work is that while these risk relationships may be defined, very little is known about how these cause-and-effect pathways may be altered by complex interventions that address risk factors at multiple levels simultaneously. To guide this exploration further, the concept of child vulnerability is introduced in order to better understand how a child's exposure to risk factors interacts with underlying capacities to respond, and enable the prediction of the expected impact of program intervention. A key question to be answered by this analysis is whether during the MICAH program there is evidence of a reduction in child vulnerability to the risk factors associated with anaemia in each program context, given its efforts to address the multifactorial causes of anaemia at the individual, household and community level. Various analytic tools, including descriptive statistics, logistic and linear regression models and population attributable risk analysis, will be applied to the datasets in an effort to build our understanding of these risk relationships. Consideration will then be given to the implications that these findings have for the design and implementation of future anaemia control programs.

This thesis starts with a review of the literature on anaemia – its causes, consequences and public health interventions to address it, as well as a summary of evidence to date on the risk factors for anaemia in children 24-59 mo in sub-Saharan African countries. Then, based on existing data and an extensive review of program documentation, the MICAH program will be described with a focus on the program area

context, targeted groups and design of interventions to address anaemia, as well as an estimate of the program's reach. Building on this evidence, I will present the rationale for this research, the theoretical framework underlying it and the specific objectives set. The methods used to collect and analyze the data will be explained, followed by a presentation of the results observed. These results will then be discussed in light of the research objectives outlined and the limitations of the data and procedures used. Finally, the potential implications for future public health nutrition programming will be discussed and conclusions drawn.

## 1.1 Role of the student

The student (K.W.) participated in the implementation and evaluation of the MICAH program in the role of a Nutrition Program Manager for World Vision Canada from 2001 to 2007, based in the Canada office for most of that time and one year in Ghana. She was responsible for the MICAH Ghana and Senegal programs, specifically, but worked in close collaboration with the other three country programs as well. She provided training and nutrition technical expertise to field program staff, regular monitoring of program implementation through reports and field visits, and technical support for the program evaluation. The student participated in the program evaluation activities in the capacity of a technical advisor, with specific responsibility for the MICAH Ghana program evaluation. This included providing input in 2004 to the survey questionnaire revisions, sampling design and data collection methods. The student and one of the advisors (O.R.) also participated in 2005 in a stakeholder workshop in Mpraeso, Ghana to review the 2004 survey results, reflect on the various factors contributing to them and provide technical support in the preparation of the final survey report. The student was a major contributor to the content of the MICAH Ghana Final Evaluation Report (World Vision Canada, 2006) and the MICAH Final Program Report 2006 (World Vision Canada, 2006). Further analysis and reviews of the evaluation results for all five MICAH program countries were also undertaken by the student during her time with World Vision Canada. Based on some of this work, the student also co-authored a study published on the MICAH program data quality and impact (Berti *et al.*, 2010).

The current study was originally designed by the student and her advisor (O.R.) and further refined in consultation with her co-advisor (S.H.). Analysis and interpretation of data was done by the student in consultation with her advisors. This document was written by the student. Helpful feedback is gratefully acknowledged from the student's advisors (O.R. and S.H.), Peter Berti (committee member) and the members of the jury.

# CHAPTER 2: LITERATURE REVIEW

# 2 Literature Review

## 2.1 Overview of anaemia as a public health problem

Due to its relationship to morbidity and mortality in children and women, anaemia prevalence is an important indicator of overall public health. Recent global estimates suggest that 47% of preschool aged children, 42% of pregnant women and 30% of non-pregnant women are anaemic, representing approximately 818 million women and young children (McLean *et al.*, 2007). Although found in every society and region of the world, the pattern of anaemia prevalence consistently shows highest levels in the poorest regions. Among preschool aged children, the highest prevalence of anaemia is in the Africa region where it is estimated to affect 65%, or 93.2 million children (McLean *et al.*, 2007). Anaemia contributes to 23% of nutrition-related disability adjusted life years in Africa (WHO, 2002).

## 2.2 Definition and pathophysiology

Anaemia is defined as the state when haemoglobin (Hb) production is lowered such that an individual's haemoglobin concentration or haematocrit is below the central 95% reference range for healthy persons of the same age and sex. When this anaemia is accompanied by laboratory evidence of iron deficiency, such as low serum ferritin (unconfounded by concurrent infection), or when there is a rise in haemoglobin in response to iron treatment, it is considered iron deficiency anaemia (Yip & Dallman 1996).

The concentration of haemoglobin in red blood cells is important due to its role of transferring oxygen from the lungs to the rest of the body. The haemoglobin molecule is made up of four polypeptide chains that each contains a haem-iron group. Each iron ion (the oxygen binding site) is held in a heterocyclic ring, known as a porphyrin. Oxygen binds to the haem-iron binding site in the lungs where the oxygen concentration is high and is released at the tissue level where oxygen levels are low. The structure of haemoglobin is essential for normal function. The synthesis of haem and globin begins

in the proerythroblast in different sites. The haem molecule is produced in the cell mitochondria and requires a sufficient supply of iron to be incorporated in each protoporphyrin ring. Various globin chain types are produced (α, β, γ, δ) in the cytoplasm and combine with haem to form different types of haemoglobin. Foetal blood contains primarily HbF ($\alpha_2\gamma_2$) with some HbA ($\alpha_2\beta_2$). Normal adult blood contains predominantly HbA (96-98%), with some HbA2 ($\alpha_2\delta_2$) and residual HbF. Defects in the genes that control the expression of the haemoglobin protein can produce abnormal haemoglobin and anaemia, conditions that are called haemoglobinopathies. This results in one of three outcomes: 1) structural defects in the haemoglobin molecule (e.g. HbS – sickle cell disease), 2) diminished production of one of the two subunits of the haemoglobin molecule (e.g. α-thalassemia), and 3) abnormal associations of otherwise normal subunits (e.g. β-thalassemia) (Bunn, 1986).

The maintenance of normal haemoglobin levels also depends on adequate red blood cell production. Red blood cells have a finite lifespan and are constantly replaced with new cells formed in the haematopoietic tissue (Koury & Ponka, 2004). While the nutritional requirements for haematopoiesis are similar to that for other tissues in the body, the availability of iron, vitamin B12 and folic acid can become limiting factors due to the high turnover of red blood cells. Iron-deficient erythropoeisis can develop as a result of inadequate iron supply, either due to true iron deficiency or to inflammation-induced sequestration of iron in macrophages (Koury & Ponka, 2004). In any case, impaired red blood cell production results in a fall in haemoglobin concentration, a reduced red cell count and reduced packed cell volume (Chanarin, 1999). This in turn reduces the oxygen carrying capacity of the blood and impairs oxygen delivery to tissues.

The effect of anaemia on an individual is related to both the impaired delivery of oxygen and the compensatory mechanisms that develop in response to this situation. These compensatory mechanisms allow an individual with chronic anaemia to essentially carry on with normal activity. The three main mechanisms are 1) an increase in the level of 2,3-diphosphoglycerate in anaemic red blood cells that reduces their affinity for oxygen and results in a greater proportion of oxygen on haemoglobin

released to tissues; 2) an acceleration of blood circulation by increasing cardiac output; and 3) increased production of erythropoietin by the kidneys that results in increased red blood cell production and extension of haematopoiesis into the fatty bone marrow (Chanarin, 1999). Under normal conditions, the body is able to correct transient anaemia due to minor blood loss or haemolysis. However, in many cases of anaemia, the kidneys may produce insufficient erythropoeisis or the bone marrow tissues are unable to adequately respond to the increase in erythropoietin (Koury & Ponka, 2004).

The degree to which functional changes occur depends on the severity of anaemia. Mild anaemia is characterized by a decrease in iron stores, which corresponds to a decrease in serum ferritin. The body normally responds by increasing iron absorption in the small intestine, preventing the progression to a more severe stage of anaemia. While there may be no evidence of adverse functional consequences at this stage, there is a degree of increased vulnerability from long-term marginal iron balance that might progress to more severe deficiency with functional consequences (Yip & Dallman 1996).

In the case of moderate anaemia, changes begin to take place in the body that reflect a lack of sufficient iron for normal production of haemoglobin and other essential iron compounds (Yip & Dallman 1996). As described above, the body compensates for the decreased oxygen carrying capacity of blood by biochemical changes to improve the oxygen unloading to tissues (Yip & Dallman 1996). When the reduction in haemoglobin is even lower, in the case of severe anaemia, it leads to tissue hypoxia (Yip & Dallman 1996).

Individuals with anaemia report feelings of tiredness, palpitations, ringing noise in their head or ears, headaches, irritability, dizziness and weakness (Chanarin, 1999). Pallor is a common sign, especially pale mucous membranes. Shortness of breath, rapid heart rate and pulse, visible arterial pulsation and systolic heart murmurs are also possible. When iron deficiency accompanies anaemia, in addition to the symptoms reported above for anaemia, individuals may experience a sore mouth and tongue, angular stomatitis (cracks at the angles of the mouth), difficulty swallowing and pica (eating clay, ice, paper, dirt), especially among children.

## 2.3 Assessment of anaemia and iron status

### 2.3.1 Haemoglobin as a measure of anaemia

The measurement of haemoglobin concentration in whole blood is the most commonly used test for anaemia and iron deficiency anaemia. However, it is important to note that haemoglobin assessment is not specific to iron deficiency, as the range of haemoglobin values for normal non-anaemic individuals overlaps with values for iron deficient individuals (Gibson, 2005). While it is best to use venous blood, capillary blood from the heel, ear or finger tip can also be used. Haemoglobin concentration is most reliably measured by the cyanmethemoglobin method, as recommended by the International Committee for Standardization in Haematology (1987). In large surveys and developing country contexts, it is often measured using a portable haemoglobin photometer (e.g. HemoCue). As long as standardization procedures for sample collection and analysis are followed, the accuracy and precision of haemoglobin values measured with the HemoCue are comparable to those obtained by the other method (Gibson, 2005).

Table 2.1 gives a summary of haemoglobin cut-offs used to define anaemia among different population groups. For children 6-59 mo, the cut-off used to define anaemia is a concentration below 110 g/L (WHO/UNICEF/UNU, 2001). Haemoglobin concentrations between 100 and 110 g/L indicate mild anaemia; concentrations between 70 and 100 g/L indicate moderate anaemia and concentrations below 70 g/L indicate severe anaemia.

Interpretation of haemoglobin levels requires taking various factors into account, including age, sex, physiological status (i.e. pregnancy), altitude, smoking and ethnicity (WHO/UNICEF/UNU, 2001; Gibson, 2005). In general, haemoglobin values increase during the first ten years of life and at puberty. Females generally have lower haemoglobin levels, especially after 12 y of age. During pregnancy, the expansion of plasma volume exceeds the concurrent increase in red cell mass and therefore haemoglobin concentration is diluted. At altitudes over 1000 m, the body adapts to the

lower oxygen pressure by increasing haemoglobin concentration. Smoking is associated with higher haemoglobin concentrations, around the order of 3-7 g/L.

Table 2.1: Haemoglobin cut-offs to define anaemia among population groups

| **Group** | **Haemoglobin below (g/L)** |
|---|---|
| Children 6-59 months | 110 |
| Children 5-11 years | 115 |
| Children 12-14 years | 120 |
| Non-pregnant women | 120 |
| Pregnant women | 110 |
| Men | 130 |

Source: WHO/UNICEF/UNU 2001

In the USA, national surveys have shown that haemoglobin values are significantly lower among African Americans than Caucasians, a difference that cannot be attributed to iron nutritional status (8 g/L for adults, 4 g/L for children under five years of age (U5) (Yip & Dallman, 1996) and 2.6 g/L for children 2-5 y (Robins & Blum, 2007)). A recent study with a national cohort of 30,228 adults (50% African American, 50% female) found that anaemia was 3-fold more common in African Americans than Caucasians, a difference that was not explained by the factors studied, including demographic variables, socioeconomic factors and co-morbid conditions (Zakai *et al.*, 2009).

Although reasons for the observed ethnic differential are not known, the evolutionary medicine perspective would suggest that the protective effect of iron deficiency against infectious bacterial diseases favours preferential selection of the iron-deficiency phenotype in populations where infectious diseases remain high (Denic & Agarwal, 2007). This protective effect has been shown for both iron deficient erythropoeisis and iron deficiency anaemia states in children 5-10 y in Kenya (Wander *et al.*, 2009). A recent study from Gabon (Central Africa) reported haematological

reference values for apparently healthy[1] children 18-60 mo, including a 95% reference interval for haemoglobin of 85-120 g/L (Humberg *et al.*, 2011). In the absence of published haemoglobin reference data derived from representative African populations, and based on the ethnic differential observed in North American studies, the WHO suggested using a haemoglobin cut-off that is 10 g/L lower for populations of African extraction in order to achieve a similar screening performance (sensitivity and specificity) (WHO/UNICEF/UNU, 2001). However, broad consensus has not been reached on this issue and cut-offs used for studies in African country contexts vary.

Haematocrit, defined as the volume fraction of packed red cells, can also be used to assess haemoglobin concentration but is technically more difficult to measure accurately (Gibson, 2005). Although a three-fold conversion is commonly used to equate haemoglobin and haematocrit measures, recent evidence from a malaria endemic setting suggests that the relationship may be modified by exposure to malaria and direct determination of haemoglobin is the measurement of choice in these areas (Carneiro *et al.*, 2007). Other red cell indices, including mean cell volume and mean cell haemoglobin, are useful in differentiating types of anaemia (Gibson, 2005). Iron deficiency anaemia is characterized by microcytic hypochromic red blood cells (low mean cell volume and mean cell haemoglobin) whereas vitamin B12 and folic acid deficiencies result in macrocytic anaemia (high mean cell volume and mean cell haemoglobin). The anaemia of chronic inflammation is characterized by normocytic normochromic red blood cells.

The public health significance of anaemia prevalence in any given population has been classified by the WHO and is presented in Table 2.2. For nearly all of sub-Saharan African countries, anaemia among preschool children is a severe public health problem (McLean et al., 2007).

[1] Although the children were followed closely over time and stringent exclusion criteria used to select a healthy reference sample group, the authors suggest that the elevated eosinophil counts observed in the children 18-60 mo may be due to highly prevalent helminth infections in the study area. Therefore, the true health status of these children is unknown and the reference values for haemoglobin of questionable use outside the study context.

### 2.3.2 Clinical assessment of anaemia

Moderate and severe anaemia may be assessed using a clinical examination to detect pallor (pale skin, mucosal linings and fingernails) but this is a relatively nonspecific symptom of anaemia and is therefore only used for screening purposes (WHO/UNICEF/UNU, 2001). The WHO has developed a diagnostic and treatment algorithm in the Integrated Management of Childhood Illness (IMCI) to assist health workers in assessing whether a child's palm is unusually pale, as compared to their own palm or those of other children (WHO/UNICEF, 2005). The IMCI manual recommends that children with severe palm pallor ("very pale or so pale that it looks white", p. 49) be suspected for severe anaemia and referred to a hospital, while children with only some pallor are diagnosed as having moderate anaemia and are treated with oral iron at the primary health care level. Studies looking at the health worker's ability to distinguish between none, some and severe pallor and the correspondence of these to none, moderate and severe anaemia have found sensitivities for pallor to detect severe anaemia ranging from 29% to 93% and specificities from 57% to 91% (Mogensen *et al.*, 2006).

Table 2.2: Classification of public health significance of anaemia in populations

| **Category of public health significance** | **Prevalence of anaemia (%)*** |
|---|---|
| Severe | ≥40 |
| Moderate | 20.0 – 39.9 |
| Mild | 5.0 – 19.9 |
| Normal | ≤4.9 |

* Prevalence estimated from blood levels of haemoglobin or haematocrit.

Adapted from WHO/UNICEF/UNU 2001.

### 2.3.3 Iron deficiency anaemia assessment

While anaemia is defined in terms of haemoglobin concentration, an individual's iron status must be assessed in order to identify iron deficiency anaemia. While there are a number of different indicators that can be used to determine an individual's iron status, many are subject to physiological variation. Regulation of iron metabolism undergoes

developmental changes during the first year of life (Lind et al. 2004). Infection and inflammatory states are also associated with changes to iron physiology, making the assessment of true iron deficiency very difficult in contexts where chronic inflammation is common.

Serum ferritin is currently the indicator of choice to evaluate the impact of interventions to control iron deficiency (WHO/CDC, 2005). An indicator of body iron stores in healthy individuals, serum ferritin levels are sensitive to tissue iron levels across a wider range than any other indicator (Beaton *et al.*, 1989). However, as an acute phase protein, it increases during infection regardless of actual iron stores, making interpretation of results difficult (Thurnham *et al.*, 2010). In individuals with no evidence of infection, a concentration of <12-15 μg/L suggests iron stores are depleted and concentrations over 15 μg/L reflect the size of the iron stores (WHO/CDC, 2005).

Free erythrocyte protoporphyrin (EPP) and zinc protoporphyrin (ZPP) levels rise when the body's iron supply is inadequate for haem production, as zinc is inserted into the protoporphyrin ring instead of iron. These red blood cells can be detected using fluorimetry (WHO/CDC, 2005). EPP and ZPP are seen as early indicators of the effect of iron depletion on erythropoeisis (Beaton *et al.*, 1989). In the recent discussions surrounding an appropriate indicator of iron deficiency in young children in malaria-endemic contexts to provide targeted iron supplementation programs, low ZPP was reported to predict risk from iron supplementation much more accurately than high haemoglobin concentration in the Pemba trial substudy (Stoltzfus *et al.*, 2007).

Mean cell volume, a measure of the size of the red blood cells, is useful in identifying iron deficiency as cells become microcytic (smaller and without full haemoglobin). It is helpful in distinguishing the anaemia due to iron deficiency from that due to folic acid and vitamin B12 deficiency (megaloblastic anaemia) (WHO/CDC, 2005).

Measures of iron being transported in the plasma (bound to transferrin) include serum iron, serum transferrin and transferrin saturation. In iron deficiency, serum iron falls below the normal range of 11-28 μmol/L, serum iron-binding capacity rises above normal range of 47-70 μmol/L and transferrin saturation falls below normal range of 16-

60% (Chanarin, 1999). Serum transferrin receptor levels are reflective of cellular iron needs and increase during early iron deficiency. Serum transferrin receptor concentration also increases in haemolytic anaemia and thalassaemia but is less affected by inflammation than serum ferritin (WHO/CDC, 2005).

## 2.4 Causes of anaemia

The causes of anaemia are complex and often multi-factorial. This review will focus on the primary causes of anaemia in young children in sub-Saharan Africa. These include iron deficiency, other micronutrient deficiencies, malaria, helminth infections, other inflammatory conditions, HIV and haemoglobinopathies (Crawley, 2004).

### 2.4.1 Iron deficiency

Iron deficiency is the most common cause of anaemia, given the direct relationship between body iron status and haemoglobin synthesis. Iron deficiency is estimated to be responsible for about 50% of anaemia globally (Stoltzfus *et al.*, 2004b). Where anaemia is prevalent, elimination of iron deficiency is expected to result in a change in mean haemoglobin of 11.7 g/L or more (Stoltzfus *et al.*, 2004b). Iron deficiency is a result of a negative iron balance due to insufficient absorption of iron, excess loss of iron or both. Young children and women are the most vulnerable groups for iron deficiency because at these stages, growing lean tissue and expanding blood volume require a significantly higher amount of iron. When these vulnerable groups also live in developing country contexts where dietary intake of bioavailable iron is low and blood loss due to hookworm infection is high, iron deficiency is prevalent.

#### 2.4.1.1 Iron in the body

The majority of iron in the body is found as a component of the haem proteins, haemoglobin and myoglobin, accounting for approximately three quarters of the body's iron. Most of the remaining iron is found as a component of storage and transport proteins such as transferrin, lactoferrin, ferritin and hemosiderin. Small amounts of iron are also found in various haem/non-haem enzymes and cytochromes.

Iron is unique in terms of its regulation in the human body since there is no excretory pathway for excess iron. Excess iron can cause tissue injury and organ failure due to its role in generating reactive oxygen species. The body therefore strictly regulates absorption of iron in the small intestine in response to iron needs and the transport of iron between cells for storage and recycling. The key components involved in iron flow are duodenal enterocytes involved in dietary iron uptake, hepatocytes that store iron and macrophages that recycle iron from senescent red blood cells (Nemeth & Ganz, 2006). Iron required to replace basal losses (approximately 1-2 mg/day in adults) or to meet increased requirements due to growth is obtained through absorption of dietary iron (Fairbanks, 1999).

Iron absorption in the small intestine varies according to the iron status and iron needs of healthy individuals. Iron stores play a critical role in the iron status of young children. At birth, the infant's iron stores are directly influenced by foetal growth, maternal iron status and delayed cord clamping (Chaparro *et al.*, 2006). Premature and low birthweight infants have low iron stores and need dietary iron earlier. Breast milk is characteristically low in iron, despite its high bioavailability, and infants rely on iron stores to meet the majority of their iron requirement in the first four to six months of life. Once these initial stores are depleted, absorption of dietary iron becomes more important to maintaining adequate iron status. During periods of high growth, as in early childhood when iron requirements are high, iron stores are usually absent or low.

A child's iron status can be seen as a continuum, ranging from the one extreme of iron deficiency with anaemia to iron deficiency without anaemia to normal iron status with varying iron stores and finally to the other extreme of iron overload (WHO/UNICEF/UNU, 2001). When the development of iron deficiency occurs gradually, due primarily to an imbalance between absorption and the sum of requirements and losses, it commonly follows a sequence of events that leads from normal iron status to the depletion of iron stores, then to a suboptimal supply of iron to the functional compartment without measurable deficiency (iron-deficient erythropoeisis) and finally to measurable shrinkage of the circulating red cell mass (iron deficiency anaemia) (Lynch *et al.*, 2007b).

#### 2.4.1.2 Iron requirements in early childhood

At an individual level, iron needs are related to many different factors, including age, gender, physiologic status and pre-existing stores. Iron requirements in early childhood are largely based on basal iron losses and the increase in iron needs due to growth, including increases in blood volume and haemoglobin concentration, tissue iron and iron stores. In the first year of life for a term infant, iron stores almost double and body weight nearly triples and in the subsequent five years of life, body iron content doubles again (WHO/FAO, 2004). As a result, absorbed iron requirements are very high in relation to energy requirements in young children. The bioavailability of iron in the diet and the child's health status also has an important bearing on iron requirements.

Table 2.3 presents a summary of the current international recommended nutrient intake (RNI) for iron among young children (WHO/FAO, 2004). The RNI is based on the estimated average bioavailability of iron in the diet. For a two-year-old healthy child, the iron requirement ranges from 3.9 mg/d for a diet with 15% bioavailability to 11.6 mg/d for a diet with only 5% bioavailability.

Based on an assessment of the energy and nutrient adequacy of 23 different complementary foods used in parts of Africa and Asia, none of the complementary foods (even those that included animal products) met the desired iron density corresponding to their assumed bioavailability level for iron. Gibson and colleagues concluded: "Even if strategies to improve the bioavailability of iron and zinc are employed, they are probably insufficient to overcome the deficits in calcium, iron and zinc" (Gibson *et al.*, 1998, p.764). Similarly, a recent effort in Indonesia to develop population-specific, food-based complementary feeding recommendations also found that "theoretical iron requirements could not be achieved using local food sources (highest level achievable, 63% of recommendations) and adequate levels of iron, niacin, zinc, and calcium were difficult to achieve" (Santika *et al.*, 2009, p.135).

Table 2.3: Summary of iron requirements for children 1-5 y

| Group | RNI for iron (mg/d), by average bioavailability of iron in the diet[1] | | | | RDA for iron (mg/d)[2] |
|---|---|---|---|---|---|
| | 15% | 12% | 10% | 5% | |
| 1-3 y | 3.9 | 4.8 | 5.8 | 11.6 | 7 |
| 4-5 y | 4.2 | 5.3 | 6.3 | 12.6 | 10 |

[1] The Recommended Nutrient Intake (RNI) is the daily intake which meets the nutrient requirements of 97.5% of healthy individuals in an age- and sex-specific population (WHO/FAO, 2004).

[2] Based on 18% bioavailability of iron in the diet. The Recommended Dietary Allowance (RDA) is an estimate of the daily average dietary intake that meets the nutrient needs of 97.5% of healthy members of a particular life stage and gender group (IOM, 2001).

Few data are available on actual iron intake of children 24-59 mo in African countries. In one community-based dietary intervention study in Malawi, the nutrient adequacy of the diets of children 3-7 y was measured (Yeudall *et al.*, 2005). Median daily intake of iron was 9.4-9.6 mg among intervention and control children, of which 0.33-0.51 mg was haem iron. Only about 1 mg was considered available iron, although the authors pointed out that this estimate did not take into account the impact of the intervention's phytate reduction strategies (Gibson *et al.*, 2003). Median daily intake of animal protein was 5.1-8.9 g; the percent of energy from animal source foods was 3-5% (Gibson *et al.*, 2003). About one third of children in control areas had energy intakes less than two-thirds of the FAO/WHO/UNU average requirement. Another study found that daily intake of iron among children 42-80 mo living in rural areas of Ghana and Malawi were very similar: 11.6 and 13.1 mg, respectively (Ferguson *et al.*, 1993). However, very high phytate levels observed in the Malawian children's diet likely limits the bioavailability of iron to a greater extent than in Ghana. Based on these studies and others, bioavailability and not intake appears to be the limiting factor in iron nutrition for older preschool children in these contexts (Gillespie & Johnston, 1998).

#### 2.4.1.3 Dietary iron absorption and bioavailability

Iron absorption depends on the source of iron (haem vs. non-haem iron) and other nutritional factors (absorption enhancers/inhibitors) as well as the iron status of the individual. Dietary iron comes in two forms. Haem iron, found in flesh foods such as

meat, fish and poultry, is highly bioavailable (average 25% absorbed; range 10 to 40%) but its absorption may be adversely influenced by the content of calcium in the meal and if foods are cooked at a high temperature for too long (WHO/FAO, 2004). Non-haem iron is the most abundant form of dietary iron, found in dairy products and eggs, and in plant foods such as beans, cereals, nuts, fruits and vegetables. Iron fortificant and "contaminants" (iron found in food from soil or other non-food sources) also contribute to non-haem iron intake. The bioavailability of non-haem iron is generally low (2 to 20%) (Ruel & Levin, 2000) and its absorption is greatly influenced by an individual's iron status and the combination of enhancing and inhibiting factors in the diet.

Ascorbic acid is a potent enhancer of non-haem iron absorption. The presence of meat, fish and seafood enhances both non-haem and haem absorption. Vitamin A is also thought to enhance the absorption of nutrients through improved gut integrity and enhanced absorption of non-haem iron (Semba & Bloem, 2002).

Inhibitors of iron absorption include phytate, phenolic compounds, calcium and soya. Phytate strongly inhibits iron absorption in a dose-dependent manner; even small amounts have a significant detrimental effect (WHO/FAO, 2004). Iron-binding phenolic compounds found in tea, coffee, cocoa, certain vegetables and most red wines also strongly inhibit iron absorption. An inhibitory effect on iron availability (20-90%) of some common spices and herbs (chilli pepper, garlic, shallot, turmeric and curry paste) that are rich in polyphenolic compounds has also been found (Tuntipopipat *et al.*, 2009). As with haem iron, calcium also interferes with non-haem iron absorption, with its effects on both forms of iron evident in meals containing over 40 mg of calcium. The addition of soya to a meal can also reduce the fraction of iron absorbed but this effect is offset in part or in whole by the additional iron found in soya (WHO/FAO, 2004).

Due to the complexity of the above dietary influences on iron bioavailability, it is very difficult to estimate the actual total amount of iron absorbed from the diet. However, it has been shown that in poor populations who have limited access to animal foods, the main sources of dietary iron are staple cereals, starchy roots, tubers and legumes and these have low bioavailability (Ruel & Levin, 2000). Based on recent

studies of iron absorption in developing country contexts, the use of bioavailability estimates of 5% or 10% are recommended (WHO/FAO, 2004).

The amount of iron absorbed in the small intestine is also determined by an individual's iron status. Iron-replete individuals with high iron stores have decreased iron absorption, especially non-haem iron. In healthy children 12-48 mo, iron absorption was more closely related to iron status than to iron intake (Lynch *et al.*, 2007a). Individuals with iron deficiency absorb iron more efficiently, up to a maximum of 4 mg/d (Fairbanks, 1999). Regulation of iron absorption may undergo developmental changes as well; infants between 6 and 9 months of age have shown an ability to adapt to a low-iron diet and, in some cases, avoid developing iron deficiency despite low iron intakes (Domellof *et al.*, 2002).

Iron absorption is also down-regulated during infection, due to the body's inflammatory response. Cytokines such as interleukin (IL)-6 stimulate expression of hepcidin and this results in decreased export of iron from enterocytes into the plasma due to the inhibitory effects of hepcidin on ferroportin expression (Hugman, 2006). The absorbed iron is lost when the enterocyte is sloughed off and excreted in feces. This mild-to-moderate type of anaemia is not responsive to iron supplementation (also called 'iron refractory anaemia') as long as hepcidin levels remain high. Recent studies also suggest that inflammation associated with obesity may also alter iron absorption (Zimmermann *et al.*, 2008; McClung & Karl, 2009).

#### 2.4.1.4 Excess loss of iron

Even if the diet provides adequate and bioavailable iron, excess loss of iron from the body can also result in iron deficiency. Iron is normally well conserved in the body once it is absorbed. However, factors causing excess blood loss in children include hookworm, a major cause of gastrointestinal blood loss (Stoltzfus *et al.*, 1997b), and schistosomiasis which causes urinary blood loss (Friedman *et al.*, 2005a). Very heavy *T. trichiura* infection resulting in Trichuris dysentery syndrome also causes considerable blood loss (Stephenson *et al.*, 2000a). Blood loss secondary to chronic *H. pylori*

infection has also been proposed as a cause of iron deficiency anaemia (DuBois & Kearney, 2005).

### 2.4.2 Vitamin A deficiency

Vitamin A deficiency remains the leading cause of child blindness and an important contributor to severe infections and child mortality in developing countries. Its contribution to anaemia is a matter of much research and there is a growing amount of evidence to support a causal relationship between vitamin A deficiency and anaemia (Semba & Bloem, 2002; West *et al.*, 2007). Observational studies have found a high prevalence of both in the same population, particularly in developing countries; the overlap in risk is greatest when both vitamin A deficiency and anaemia are high. For example, among preschool children in the Marshall Islands, 60% had vitamin A deficiency (serum retinol <70 μmol/L), 36% had anaemia (Hb <110 g/L) and 33% had both (Palafox *et al.*, 2003). However, among Venezuelan children 24-84 mo, 22% had vitamin A deficiency (serum retinol <70 μmol/L), 38% were anaemic (Hb <110 g/L if <72 mo, Hb <115 g/L if 72-84 mo) but only 8% had both (Castejon *et al.*, 2004). Since iron deficiency may lower serum retinol concentrations, there is also some concern that vitamin A deficiency may be overestimated in populations (Villalpando *et al.*, 2006a).

Evidence for a significant haemoglobin response among children receiving vitamin A supplementation has also bolstered the argument for a causal relationship. Based on a review of vitamin A supplementation intervention studies in children, it is estimated that improving vitamin A status can achieve approximately 3-10 g/L increase in haemoglobin when given to anaemic and mildly vitamin A deficient individuals (West *et al.*, 2007). For example, a placebo-controlled trial of vitamin A supplementation in malaria-free school-age children with poor vitamin A and iron status found that vitamin A supplementation increased mean haemoglobin by 7 g/L ($p<0.02$) and reduced the prevalence of anaemia from 54% to 38% ($p<0.01$) (Zimmermann *et al.*, 2006).

The relationship between vitamin A and iron is complex and the exact mechanism of vitamin A deficiency on anaemia has not yet been elucidated. The

evidence to date supports a role for vitamin A in enhancing hepatic tissue mobilization and delivery of iron to bone marrow as well as a role in improving erythropoeisis by up-regulating erythropoietin production and extending red blood cell life (Zimmermann *et al.*, 2006; West *et al.*, 2007). During vitamin A deficiency, iron is trapped in the liver and spleen and is not effectively released for erythropoeisis by bone marrow. However, this relationship may be more complex in malaria-endemic contexts, since both *Plasmodium falciparum* malaria and vitamin A have an effect on erythropoietin production (Cusick *et al.*, 2005).

Vitamin A may also play a role in the absorption of iron and other nutrients; increased vitamin A in infants resulted in improved gut integrity and enhanced absorption of non-haem iron in adults (Semba & Bloem, 2002). Finally, a fourth possible role is that adequate vitamin A reduces the severity of infections and thereby reduces the sequestration of iron due to anaemia of inflammation. However, evidence to support this specific mechanism is not yet conclusive (West *et al.*, 2007).

### 2.4.3 Other micronutrient deficiencies

The maintenance of normal haematopoiesis requires adequate levels of many other nutrients (Fishman *et al.*, 2000). Those that play important roles in iron absorption and metabolism include vitamins B12, C and E, riboflavin and folic acid; further discussion of these is found below. Vitamin B6 deficiency is rare but has been observed to disturb haem synthesis and lead to normocytic, microcytic or sideroblastic anaemia. Thiamine, niacin and pantothenic acid have also been related to human anaemia but their public health significance is not known. Although micronutrient deficiencies are often studied in isolation, they regularly occur together, especially in contexts where the nutritional adequacy of diets is low. The sparse evidence presented below for the direct contribution to anaemia in young children of each nutrient deficiency is reflective of this complexity.

Folate and vitamin B12 are essential for erythropoeisis and a deficiency of one or both vitamins can result in megaloblastic anaemia, characterized by macrocytosis (Fishman *et al.*, 2000). Periods of highest risk for deficiency include early infancy for

low birthweight infants, pregnancy and lactation for women, and the elderly. There is also some evidence of a higher risk of folate deficiency in malaria-endemic regions due to the impact of malarial haemolysis (Fishman *et al.*, 2000), but this has not been demonstrated in children (Metz, 2007). There is also no convincing evidence that folic acid supplements improve the haematological status of children who have a malaria attack, with or without anaemia (van Hensbroek *et al.*, 1995; Metz, 2007). Very little is known about the prevalence of folate and vitamin B12 deficiency among young children, particularly in African countries (McLean *et al.*, 2008). Although many children are undernourished in general, there is little direct evidence of widespread folate deficiency (Metz, 2007). Despite the low intake of animal source foods among poorer households, anaemia due to nutritional vitamin B12 deficiency does not seem to be a widespread problem (Metz, 2008). A recent review concluded that the contribution of folate and vitamin B12 deficiencies to the burden of anaemia in developing countries was likely not significant (Metz, 2008).

Riboflavin deficiency has also been implicated as a contributing factor to anaemia, due to evidence that it impairs iron mobilization, globin synthesis and iron absorption (Fishman *et al.*, 2000). Effects of riboflavin deficiency on the development of the gastrointestinal tract may be important in the aetiology of both anaemia and growth impairment associated with this deficiency, due to the impact that these changes have on the efficiency of nutrient absorption (Powers, 2003). Riboflavin deficiency is common in populations where intake of dairy products and meat is low (Powers, 2003). The few studies that have been done among African children suggest that riboflavin deficiency is indeed widespread, affecting approximately one third of children studied in Botswana (Abrams *et al.*, 2003) and Kenya (Siekmann *et al.*, 2003). Riboflavin intake in South African children 2-5 y was less than half of the recommended daily allowance (Faber *et al.*, 2001). However, a recent study of children 5-15 y in Cote d'Ivoire found that although 52% were anaemic and 65% had riboflavin deficiency, riboflavin deficiency did not predict haemoglobin or anaemia in this group (Rohner *et al.*, 2007). Results have been mixed in terms of the effect observed in riboflavin supplementation trials on improved haematological status and response to iron supplementation (Fishman *et al.*, 2000).

Vitamin C and E are both known for their antioxidant functions in the body. During malaria infection, increased production of reactive oxygen species in the presence of inadequate oxidative defence may damage the erythrocyte membrane and contribute to anaemia (Crawley, 2004). Alpha-tocopherol is the principal anti-oxidant in cell membranes, and reduced levels in erythrocyte membranes have been documented in children with malarial anaemia (Crawley, 2004). Vitamin C also improves absorption of non-haem iron when consumed together and counteracts the effects of iron absorption inhibitors (Fishman *et al.*, 2000). Nutritional deficiencies of vitamin C and E in young children are thought to be uncommon.

### 2.4.4 Malaria

Malaria is an important contributing factor to anaemia, particularly in areas where its transmission is endemic. Among children U5 in Africa, estimates of the overall incidence of severe malarial anaemia range from 3.6 (Roca-Feltrer *et al.*, 2008) to 15–60 (Murphy & Breman, 2001) cases per 1,000 children per year. Malaria is believed to be the primary cause of severe anaemia (Hb <7 g/L) in at least 50% of people living in malaria-endemic areas (Gillespie & Johnston, 1998). Studies of infants and young children in Tanzania found that malaria was the largest contributor to the aetiology of severe anaemia, with an estimated 60% of anaemia cases due to malaria and only 30% due to iron deficiency (Menendez *et al.*, 1997; Abdulla *et al.*, 2001).

Malarial anaemia is defined by the WHO as Hb <50 g/L or haematocrit <0.15 in the presence of *P. falciparum* parasitaemia (>10,000 parasites per μL) with normocytic red blood cells (Nussenblatt & Semba, 2002). In practice, however, Hb <110 g/L in the presence of a blood smear showing *P. falciparum* parasites is often used to denote malarial anaemia.

Malarial anaemia is caused by the destruction of red blood cells (haemolysis) by parasites and impaired compensation for this by bone marrow dysfunction (dyserythropoeisis) (Ekvall, 2003). The relative contribution of each to the development of anaemia varies by several factors but it is likely that the severity of anaemia in acute malaria depends on the degree of red blood cell destruction whereas impaired

erythropoeisis may be of greater importance in chronic infection with low parasitaemia (Ekvall, 2003). Haemolysis occurs both during an acute attack of malaria and in association with high-density asymptomatic infections (Kitua *et al.*, 1997). In malaria endemic contexts, there are two main clinical patterns observed for anaemia in young children. In one pattern, severe anaemia develops rapidly following an acute attack of malaria. In the second pattern, anaemia is chronic and is found among children with a longer history of febrile illness, and general symptoms of ill health, often without fever (Kitua *et al.*, 1997).

The effect of malaria on anaemia is mediated, in part, by parasite factors, including the type of infecting organism, endemicity of malaria and degree of antimalarial drug resistance. The degree of anaemia caused by malaria is related to the type of infecting organism. *P. vivax, ovale* and *malariae* only infect certain types of red blood cells and therefore limit parasitaemia to 1-2%; *P. falciparum* invades all red blood cells and may result in levels of parasitaemia exceeding 50%, increasing the likelihood of severe haemolysis. Children with a higher density of parasitaemia experience a greater negative effect on haemoglobin levels and increased severity of anaemia.

Parasite factors also include the endemicity of malaria and the degree of antimalarial drug resistance. The intensity of malaria transmission influences the type of malarial morbidity and severity of malarial anaemia, with areas of high and sustained transmission having more cases of severe anaemia. Areas with low or seasonal transmission tend to have increased risk of cerebral malaria. When parasites are resistant to drugs and treatment fails to clear parasites completely, full haematological recovery is prevented in children (Ekvall, 2003).

Although many studies analyze the effect of concurrent parasitaemia on anaemia, longitudinal studies have shown that historical infection and parasitaemia densities are also important. Among children <24 mo in Kenya, increased parasitaemia density in the 90 days preceding haemoglobin measurement was more strongly associated with mean haemoglobin levels than concurrent parasitaemia density (McElroy *et al.*, 2000). However, concurrent parasitaemia was still significantly associated with lower mean haemoglobin, especially when compared to children with no concurrent parasitaemia. In

a study of infants in Tanzania, the degree of anaemia was strongly related to the parasite densities experienced over time and only weakly related to the cumulative effects of acute episodes (Kitua *et al.*, 1997).

Host factors also mediate the effect of malaria on anaemia and these include age, genetics, micronutrient deficiencies and other infections. Young children develop anaemia more frequently than older children, independent of their higher parasitaemia and even in low endemic areas (Ekvall, 2003). In a study of children U5 in Zanzibar, Tanzania, malaria parasite density was the strongest predictor of haemoglobin levels in younger children (<30 mo) but had no predictive value in children >30 mo (Stoltzfus *et al.*, 2000). Carneiro and colleagues also observed a strong age-related pattern in northeastern Tanzania; they estimated the prevalence of Hb <80 g/L attributable to malaria as 4.6% in the first year of life, 4.1% and 2.7% in children 1 and 2 years of age, respectively, and 0.8% in the 5-9 year-old age group (2006). Similar results were observed in Kenya (Bloland *et al.*, 1999).

One reason for these age-related effects is that children living in endemic areas develop partial immunity to malaria over time that results in a lower risk of clinical episodes. In studies conducted in Ghana and Tanzania, children with low density parasitaemia were at a lower risk of developing a febrile malaria episode compared to children without detectable parasitaemia or with higher levels of parasitaemia (Ofori *et al.*, 2002; Lusingu *et al.*, 2004). Increasing age was associated with a significant trend in odds ratios in favour of developing asymptomatic parasitaemia rather than febrile malaria among children U5 in two studies in Kenya as well (Bloland *et al.*, 1999). However, although children in high transmission areas develop the ability to limit the effects of low density infections, parasitaemia continues to have haematological consequences long after it loses its association with fever (Bloland *et al.*, 1999). This is evident in two of these studies that documented a markedly higher risk of developing anaemia among children with low-density parasitaemia compared to children who were slide negative. The risk of developing anaemia was 4.4 times higher (95% CI 1.10, 17.69) in the Tanzanian context (Lusingu *et al.*, 2004) and the relative risk was 1.2 (95% CI 1.0, 1.3) for children 12-59 mo with low-density parasitaemia in the Kenyan context

(Bloland *et al.*, 1999). In contrast to the benefits of exposure to malaria, a recent study found that some children in Kenya who were exposed to malaria before birth (*in utero*) had a 60% greater risk of malaria infection in their first 3 years of life and lower haemoglobin levels, compared to those who were not exposed (Malhotra *et al.*, 2009).

Genetic factors, such as sickle cell, may actually protect against severe malarial anaemia (Ekvall, 2003). The red cell abnormalities observed in West Africa also may play a significant role in influencing susceptibility to and clinical outcome of malaria infections (Mockenhaupt *et al.*, 1999; Mockenhaupt *et al.*, 2004).

Poor nutrition and micronutrient deficiencies also play an important role in the pathogenesis of malaria and malarial anaemia (Crawley, 2004). Although the relationship between malaria and protein energy malnutrition is controversial, recent evidence from community-based studies has shown that undernourished children are at greater risk of malaria (Caulfield *et al.*, 2004). For example, Friedman and colleagues (2005b) found no evidence of a protective effect of mild-to-moderate undernutrition on malaria. Instead, stunted children 0-36 mo in their Kenyan study had significantly higher odds for concurrent malaria, high density parasitaemia and severe malarial anaemia. The presence of wasting increased the risk for only severe malarial anaemia. Based on analysis conducted for the WHO Comparative Risk Assessment, the worldwide attributable risk fraction of malaria morbidity was 8.2% for WAZ <-2 SD, with similar fractions (8.4% and 8.1%) in the African regions D and E[2], respectively (Caulfield *et al.*, 2004). Micronutrient deficiencies, including iron, also interact with malaria and may influence the development of malarial anaemia. The direction of this relationship is not known, since the high-risk periods for iron deficiency and malarial anaemia coincide in late infancy (Ekvall, 2003). Beneficial protective effects of vitamin A and zinc on malaria-related morbidity have also been demonstrated, including a recent trial among children 6-72 mo in Burkina Faso where vitamin A and zinc supplements for six months

[2] AFR-D = Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, and Togo; AFR-E = Botswana, Burundi, Central African Republic, Congo, Cote d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, and Zimbabwe.

reduced the risk of fever and clinical malaria episodes as well as the prevalence of anaemia among supplemented children (Zeba *et al.*, 2008).

Finally, HIV and other parasitic and bacterial infections can also modify the effect of malaria on anaemia in different individuals (Ekvall, 2003). A detailed discussion of the effects of polyparasitism follows below. Children infected with both HIV and malaria were found to be more anaemic, and to have more severe anaemia (Hb <50 g/L), than children with either infection alone in studies in Kenya (van Eijk *et al.*, 2002; Otieno *et al.*, 2006). Further investigation is required to determine whether this is simply the additive effect of two risk factors for anaemia or the result of a biological interaction (Calis *et al.*, 2008). Since there is extensive overlap of malaria and HIV infection in sub-Saharan Africa, even modest interactions between them would have enormous public health importance (Slutsker & Marston, 2007). It has been suggested that malaria may make individuals more susceptible to other infections. Several large trials have shown that use of insecticide-treated bednets is associated with a decrease in anaemia and all-cause mortality that is greater than can be accounted for by the decrease in malaria infections alone (Snow *et al.*, 1999). However, the mechanisms underlying this finding are not yet clear. It is possible that indirect mechanisms play a role, such as malaria's effect during pregnancy on low birth weight or other nutritional and haematological influences of malaria infection (Snow *et al.*, 2003).

### 2.4.5 Other parasitic infections

In addition to malaria, there are several other tropical parasites that have a measurable impact on anaemia risk. The best known and researched are the soil-transmitted helminths and schistosomiasis. These diseases are found disproportionately more prevalent in communities characterized by poverty and in need of better housing, sanitation, water supplies, health care and education (Stephenson *et al.*, 2000b). The following paragraphs review the specific effects on anaemia of each group of parasites and then discuss the synergistic effects of concurrent multiple infections.

#### 2.4.5.1 Helminths

Three types of soil-transmitted helminths commonly affect children in sub-Saharan African contexts: roundworms (*Ascaris lumbricoides*), whipworms (*Trichuris trichiura*) and hookworms (*Necator americanus* or *Ancylostoma duodenale*). In countries where these infections are endemic, children are exposed to infections soon after birth and infection intensity increases during childhood (Bethony *et al.*, 2006). In a given population, the majority of individuals harbour relatively few worms and a small number of individuals harbour the most worms (Crompton & Nesheim, 2002). Helminth infections are associated with malnutrition, linear growth stunting and iron deficiency anaemia (Crompton & Nesheim, 2002). While all contribute in varying degrees to anaemia, the relative contribution of each species is governed by different mechanisms for initiating and maintaining anaemia (Ezeamama *et al.*, 2008). The degree of morbidity is normally related to the intensity of infection and may be due to direct and indirect effects of the worms on the gut, including blood loss, mucosal damage, secondary infection and malabsorption (Bethony *et al.*, 2006).

There is strong evidence that *A. lumbricoides* infection contributes to growth deficits in children and it has a small but significant inverse association with haemoglobin (Crompton & Nesheim, 2002). Light infections with *T. trichiura* are not associated with anaemia but *Trichuris* dysentery syndrome is associated with severe anaemia (Stephenson *et al.*, 2000a).

Hookworm infection leads to iron deficiency anaemia primarily through chronic intestinal blood loss resulting from the feeding habits of hookworms in the upper small intestinal mucosa (Stoltzfus *et al.*, 1997b). The amount of blood loss is related to the intensity of infection (i.e. the worm load). In a study quantifying the blood loss among school-age children, children with a heavy hookworm infection had a daily loss of over 2 mg iron, more than double the median iron requirement of a healthy school-age child (Stoltzfus *et al.*, 1996). In populations where iron deficiency may already be a problem due to low iron intake and bioavailability, even light hookworm infections may be sufficient to cause anaemia because of depleted iron stores (Stoltzfus *et al.*, 1997b).

Population studies have also found a significant correlation between haemoglobin levels and indicators of worm infection intensity (Stoltzfus *et al.*, 1997b).

Beyond the direct effect of helminth infections on intestinal iron losses, their nutritional impact includes anorexia, competition for nutrients and decreased nutrient absorption (Bethony *et al.*, 2006). Infection reduces appetite which in turn lowers energy, protein, fat and micronutrient intake. This may be the mechanism for the negative effect on child growth. Helminth infections also reduce the absorption and utilization of vitamin A. Evidence suggests that helminth infection in early childhood may cause an inflammatory response that is detrimental to nutrient metabolism, appetite and erythropoeisis (Crompton & Nesheim, 2002; Stoltzfus *et al.*, 2004a). The resulting anaemia of inflammation is discussed in greater detail below. Based on these multi-dimensional effects, the contribution of even mild helminth infections in young children to growth deficits and anaemia may be underestimated to date.

Historically, hookworm has been considered relatively unimportant in preschoolers and has not been studied in detail because prevalence and egg counts are lower than in older children who have had more time to acquire significant worm loads (Stephenson *et al.*, 2000b). However, studies in Kenya and Tanzania have shown that hookworm infection plays an important role in the epidemiology of anaemia in younger children. Among children 6-76 mo in rural Kenya, 29% were infected with hookworm and 20% and 15% of children were infected with *A. lumbricoides* and *T. trichiura*, respectively (Brooker *et al.*, 1999). The mean intensity and prevalence of heavy infection increased significantly with age. Children heavily infected with hookworm (>200 eggs/g feces) had a five times higher risk of anaemia compared to uninfected or lightly infected children (95% CI 1.4, 17.4). A study among children 4-71 mo in Zanzibar also found a high prevalence of infection with hookworm (51% overall), *A. lumbricoides* (40%) and *T. trichiura* (68%) (Stoltzfus *et al.*, 2000). A strong age effect was also observed in this context, as hookworm infection prevalence increased from 17% among children 4-11 mo to 84% in children 60-71 mo. In a linear regression model adjusted for malaria parasite density, haemoglobin concentrations in children ≥30 mo decreased strongly with increasing hookworm infection intensity; heavily infected

children (>4000 eggs/g feces) had haemoglobin 19 g/L lower than uninfected children. Results from both studies confirmed that heavy infections are not common until four years of age and above, due in part to the limited mobility and thus lower exposure to soil of very young children and the time required for worm loads to increase. Other studies of pre-school children in African countries have not found a significant association between hookworm infection and haemoglobin concentration, possibly because of the low prevalence of infection (<10%) in these studies (Akinkugbe, 1980; Tatala *et al.*, 1998).

Furthermore, studies of the effect of deworming programs on the nutritional status of children U5 have shown positive outcomes, both in terms of haemoglobin concentration (Gulani *et al.*, 2007) and weight gain (Alderman *et al.*, 2006). Even when worm infection levels (12% with any helminth, 6% hookworm) seemed relatively unimportant in a group of children 2-4 y in Kenya, a single dose of mebendazole resulted in significant gains in weight and height at 6 month follow-up, emphasizing the importance of addressing these infections in these younger children (Manjrekar, 1999).

#### 2.4.5.2 Schistosomiasis

There are three major schistosome species that cause human disease (*Schistosoma mansoni, S. haematobium* and *S. japonicum*) and it is likely that there are multiple mechanisms, some that are species-specific, by which these parasites mediate anaemia. Proposed mechanisms include iron deficiency due to blood loss in urine or stools, splenomegaly with sequestration of red blood cells, autoimmune haemolysis and anaemia of inflammation (Friedman *et al.*, 2005a). As with helminth infections, the likelihood that an infected individual experiences a decrease in haemoglobin concentration depends on the intensity of infection and the degree of iron deficiency caused by other infections and dietary intake. The mean iron loss in children heavily infected (208-1194 eggs/10 ml) was approximately 652 μg/day, an amount similar to average daily menstrual losses (Gillespie & Johnston, 1998).

Although the peak prevalence and intensity of schistosomiasis occurs in children 10-15 y (Friedman *et al.*, 2005a), several studies have shown that infection can be a

problem of public health importance in infants and preschool children, with observed prevalence ranging from 27 to 72% (Friis *et al.*, 1997; Mafiana *et al.*, 2003; Bosompem *et al.*, 2004; Odogwu *et al.*, 2006; Garba *et al.*, 2010). The impact on haemoglobin concentration in these children was not assessed. Most children acquire their first exposure when they are able to accompany a member of the family to an infested river or pond but some children are infected in the first two years of life through passive means, such as being bathed in water that was taken by their caregiver from an infested water source (Stothard & Gabrielli, 2007).

#### 2.4.5.3 Polyparasitism

Increased attention is now being given to the health impacts of polyparasitism, with studies looking at the effects of infection with multiple helminth species as well as malaria and helminth co-infection. Given the distinct mechanisms by which malaria, helminths and schistosomes reduce haemoglobin levels, the impact of multiple species infections is expected to be additive (Pullan & Brooker, 2008). But multi-species, low-intensity parasitic infections have been shown to be associated with higher odds of anaemia among school-age children relative to their uninfected counterparts or those with one low-intensity infection (i.e. synergy of effect – greater than sum of individual effects). In a study in the Philippines, the risk of anaemia was greater than the sum of risks for individual infections among children with simultaneous exposure to hookworm and schistosomiasis, as well as among children with hookworm and trichuris (Ezeamama *et al.*, 2008).

Researchers in Africa have also coined a term, “the perfect storm of anaemia” (Pullan & Brooker, 2008), for the enhancement in anaemia as a consequence of co-infection with malaria and other tropical diseases (e.g. hookworm, schistosomiasis). Reanalysis of data from Kenya showed that haemoglobin concentrations were lower among preschool children harbouring hookworm and malaria co-infections compared to children with single species infections, with similar results among school-age children but no difference among pregnant women (Brooker *et al.*, 2007). However, the authors point out that the prevalence of co-infection in preschool children was much lower than in school-age children (3.5% vs. 35.2% co-infected, respectively) and therefore the

public health significance of co-infection among younger children remains to be seen. Co-infection with malaria and helminths among school-age children in Ghana was found to modulate the immune response to malarial parasites, making it more anti-inflammatory (Hartgers *et al.*, 2009).

In contrast to the studies showing evidence of synergistic effects, two studies in West Africa have shown a protective effect of schistosomiasis infection on malaria infection among children 3-15 y in Senegal (Briand *et al.*, 2005) and children 4-14 y in Mali (Lyke *et al.*, 2005). In the Mali study, they did not find reduced haemoglobin levels in children infected with *S. haematobium*, lowering the likelihood that iron deficiency anaemia was the mechanism for protection against malaria. It is more likely that the protective effect was immunologically mediated (Lyke *et al.*, 2005).

### 2.4.6 Anaemia of inflammation

Another important cause of anaemia is the body's inflammatory response to infection and chronic disease. The most frequent conditions associated with anaemia of inflammation are acute and chronic infections, including bacterial, parasitic, fungal and viral infections (including HIV and tuberculosis), cancer, autoimmune diseases and chronic kidney disease (Weiss & Goodnough, 2005). The inflammatory response, also known as the acute phase response, to an external or internal stimulus triggers a cascade of physiological changes that are believed to give the body an advantage over the pathogen. One of these changes is a cytokine-mediated increase in hepcidin production that causes a reduced export of iron from enterocytes, hepatocytes and macrophages, resulting in hypoferremia that limits haemoglobin synthesis and erythrocyte production. There is a direct link between the onset of an infection and the changes in iron status, as the body seeks to prevent invading pathogens from gaining iron from the various sources in the body (Ratledge, 2007). The rapid decrease in the plasma concentration of iron and other nutrients, irrespective of nutritional status, increases the risk of anaemia and may be one of the main aetiological factors responsible for the initiation and persistence of high levels of anaemia in developing countries (Thurnham & Northrop-Clewes, 2007).

Anaemia of inflammation is characteristically normochromic and normocytic, usually of mild to moderate severity (Weiss & Goodnough, 2005). Individuals with anaemia of inflammation and concomitant iron deficiency anaemia more frequently have microcytes and more severe anaemia compared with those with anaemia of inflammation alone (Weiss & Goodnough, 2005). Anaemia of inflammation is resistant to iron supplementation (also called 'iron refractory anaemia') as long as hepcidin levels remain high, since increased iron intake may be absorbed but will not be able to be exported into the plasma due to the inhibitory effects of hepcidin on ferroportin expression (Nemeth & Ganz, 2006).

The proportion of anaemia due to inflammation has not been directly quantified for young children in developing countries. However, due to poverty, unsanitary conditions and inadequate health care, these children are frequently exposed to disease and have high levels of morbidity such as diarrhoea, respiratory illness, skin diseases and malaria (Thurnham *et al.*, 2005). Even when children begin to develop immunity to specific diseases and no longer experience the same severity of morbidity, they still need to mount an immune response to each inflammatory stimulus and therefore will experience the effects of subclinical inflammation on a frequent basis. The fact that even apparently healthy children can have elevated inflammatory markers has important implications for the assessment of anaemia and specific nutrient deficiencies in these children as well as for the design of interventions to address anaemia in these contexts (Thurnham *et al.*, 2005).

Although the inflammatory response is a normal function of the body's innate immune system and plasma concentrations of nutrients fall irrespective of nutritional status, this decrease in nutrient availability may have more serious functional consequences for children with prolonged infection and those who were already malnourished at the outset, including a reduced ability to deal with the infection (Thurnham & Northrop-Clewes, 2007). However, there is general consensus that the anaemia associated with an inflammatory response may be beneficial or protective, particularly for children living in areas with high exposure to infection (Ratledge, 2007; Stoltzfus *et al.*, 2007; Thurnham & Northrop-Clewes, 2007).

### 2.4.7 Human immunodeficiency virus (HIV)

Human immunodeficiency virus (HIV) infection is increasingly recognized as a cause of anaemia in children and adults, although its relative contribution to the burden of anaemia is difficult to determine in most contexts where HIV prevalence among young children is often unknown. In a recent review of HIV-associated anaemia in children in tropical settings, mild (Hb <110 g/L) and moderate (Hb <90 g/L) anaemia were more prevalent (OR 3.6; 95% CI 2.8, 4.7 and OR 3.0; 95% CI 2.3, 3.8, respectively) and mean haemoglobin levels were lower (standardized mean difference 6.0 g/L; 95% CI 4.9, 7.2) with HIV infection (Calis *et al.*, 2008). Similar to adults, children with more advanced disease had higher anaemia prevalence and anaemia was an independent risk factor for disease progression and death in four of five longitudinal studies reviewed (Calis *et al.*, 2008). There is evidence that HIV-exposed but uninfected children may also experience a heavier burden of anaemia, as these children have been shown to experience increased severity of infectious morbidity (Slogrove *et al.*, 2010). This group of children represents a much larger number than those who are infected and thus raises the public health importance of HIV exposure as a risk factor for anaemia.

Insufficient production of erythrocytes appears to be the most important mechanism for anaemia in HIV-infected children, with a diverse aetiology ranging from the direct effect of HIV on erythropoeisis to HIV-associated infections and neoplasms, medications and micronutrient deficiencies (Calis *et al.*, 2008). Although iron deficiency is common in HIV-infected children, two controlled studies of infants in Uganda (Totin *et al.*, 2002) and Zimbabwe (Miller *et al.*, 2006) found that levels were similar to those in uninfected children. Deficiencies of vitamin A and zinc, however, appeared to occur more frequently in HIV-infected children than those without infection (Calis *et al.*, 2008). Low vitamin D status has also been shown recently to increase the risk (RR 1.46; 95% CI 1.09, 1.96) of developing severe anaemia among HIV-infected pregnant women in Tanzania (Mehta *et al.*, 2010). Studies in adults suggest that HIV may contribute to the burden of malarial anaemia by increasing risk for parasitaemia, severe anaemia, and treatment failure (Tolentino & Friedman, 2007); however, results to date in children

show only an increased risk of anaemia and more severe anaemia among those with both HIV and malaria (Calis *et al.*, 2008).

### 2.4.8 Haemoglobinopathies

Haemoglobinopathies are a group of inherited blood conditions in which defects in the genes that control the expression of the haemoglobin protein produce abnormal haemoglobin. The most common of these are sickle cell disease and thalassemia. Both are common in the same populations and therefore some individuals inherit a gene for thalassemia from one parent and a gene for a haemoglobin variant from the other parent; one important disease of this type is sickle cell thalassemia (Weatherall, 1997).

Sickle cell disease is caused by a mutation of the β-globin gene that results in erythrocytes which become crescent or sickled in shape when deoxygenated (Stuart & Nagel, 2004). The sickle shaped erythrocyte loses its flexibility to navigate capillaries (leading to vaso-occlusion) and has a much shorter lifespan (reduced from 120 d to 10-12 d), thus becoming a direct causative factor for chronic haemolytic anaemia (Serjeant, 1997; Stuart & Nagel, 2004). Compensatory measures help to establish a new haematological equilibrium with haemoglobin levels of 60-90 g/L and tissue oxygen delivery is near-normal due to the increased rate of circulation and lower oxygen affinity of HbS (Serjeant, 1997). The increased rate of erythropoeisis increases folic acid requirements and also may compete for energy and protein, resulting in impaired growth (Serjeant, 1997).

Up to 30% of adults in Africa are carriers (heterozygous, HbS – "sickle cell trait") and 1-2% of infants are born with sickle cell disease (homozygous, HbSS – "sickle cell anaemia") (Gillespie & Johnston 1998). Among people of West African ancestry, the second most common abnormal Hb gene is sickle cell/HbC (HbSC) disease which tends to result in milder symptoms than HbSS (Serjeant, 1997). The sickle gene has the biological advantage of protecting heterozygous carriers from succumbing to endemic *P. falciparum* malaria infection but the disadvantage of premature death among homozygous individuals (Stuart & Nagel, 2004). Red blood cells containing HbS create an environment that is hostile to the development and survival of *P. falciparum*. Authors

of a study in Kenya that found the protection conferred by HbAS as highly specific to *P. falciparum* malaria noted that children with HbAS enjoy a double advantage in terms of their risk of malaria-associated severe anaemia: 1) their normal haemoglobin levels may be higher because they suffer fewer clinical attacks of malaria, and 2) they are further protected by the lower parasite densities achieved during clinical episodes (Williams *et al.*, 2005). Children with HbSS in Kenya have been shown to have lower haemoglobin levels than controls, with a mean difference of 34 g/L (95% CI 31, 37) (Williams *et al.*, 2005). In a prospective case-control study of children 2-59 mo in Kenya (56% of sample <1 y old), 2.8% of children had HbSS and 6.9% had HbAS but neither genotype was significantly associated with anaemia (Kahigwa *et al.*, 2002). Even lower levels were found in a national sample of 1057 children in Guinea-Bissau, West Africa, where the prevalence of sickle cell trait (HbAS) and sickle cell disease (HbSS) was 4.7% and 0.2%, respectively (Masmas *et al.*, 2006). Due to this low prevalence, the public health significance of sickle cell as a cause of anaemia tends to be low.

The thalassaemias are a group of inherited blood disorders in which the genes are defective in the amount of haemoglobin they produce and therefore the normal haemoglobin protein is produced in lower amounts than needed. β-thalassaemia is caused by reduced or absent production of β-globin chains, leading to an excess of α-globin chains, which accumulate in red blood cells causing damage and leading to ineffective erythropoeisis, chronic haemolytic anaemia and marrow hyperplasia (Howard & Davies, 2007). α-thalassaemia is caused by the loss of one or more of the four α-chains; individuals with HbH disease (three-gene deletion) have a milder illness characterized by anaemia and splenomegaly while those with α-thalassaemia trait (one or two-gene deletion) have a mild hypochromic anaemia (Weatherall, 1997). Similar to sickle cell trait, evidence suggests that $\alpha^{+}$-thalassemia is protective for malaria. Although the risk of severe malaria was reduced by 60% and 34% in homozygous and heterozygous children, respectively, in a case-control study in Papua New Guinea (Allen *et al.*, 1997), results from studies in Africa have been mixed, with three studies finding no evidence of protection (Allen *et al.*, 1993; Lell *et al.*, 1999; Mockenhaupt *et al.*, 1999) and one study from Ghana finding that heterozygous children had reduced odds of severe malaria compared with controls (OR 0.74; 95% CI 0.56, 0.98) (Mockenhaupt *et*

*al.*, 2004). However, results from the study on children in Nigeria showed less pronounced malaria-associated anaemia in those with homozygous α-thalassemia, suggesting that α-thalassemia and its associated microcytosis may limit the severity of *P. falciparum* malaria rather than prevent infection (Mockenhaupt *et al.*, 1999).[3] Results from community-based surveys conducted among afebrile children (0.5–8 y) in Kenya and Tanzania support this interpretation, where the protective effect of α-thalassemia against malaria-associated anaemia was not confined to severe malaria cases but was also present in mild, predominantly asymptomatic *P. falciparum* infections accompanied by inflammation (Veenemans *et al.*, 2008).

### 2.4.9 Undernutrition

In most contexts where anaemia is a public health problem, high levels of undernutrition are also evident, and the two conditions often coexist in young children. Undernutrition and anaemia share many aetiological factors, including low quality diets, low nutrient bioavailability and high rates of morbidity. However, the risk relationship between anaemia and the nutritional status of young children, as measured by physical growth, is not well-characterized in the literature. In addition to the direct impact of severe protein energy malnutrition on a child's haematological status, other possible indirect pathways of cause-and-effect are through undernutrition's effects on a child's response to micronutrient interventions and increased vulnerability to infections. Intergenerational nutritional factors have also been shown to directly influence childhood iron and anaemia status.

Protein energy malnutrition has been identified as a direct cause of anaemia. Children suffering from severe forms of malnutrition frequently have a moderately reduced haemoglobin concentration (80-100 g/L). The reduction in red blood cell mass may be due to the body's general adaptive response to starvation or it may be due to a specific constraint on the availability of energy, protein or another nutrient (Jackson, 2007). Malnourished individuals are also highly susceptible to infection and frequently have multiple deficiencies of nutrients, therefore it is difficult to identify the relative

[3] The authors go further to suggest that the microcytosis found in iron deficiency may function in a similar manner, limiting the anaemia associated with malaria infection.

contribution of these multiple potential causes to anaemia or to determine whether the overall effect on anaemia is additive or interactive (Jackson, 2007).

The importance of overall nutrition, not only single nutrients such as iron, to optimal growth and haematological status has been identified by several studies in young children. In particular, in the analysis of iron supplementation trials where a lack of haemoglobin response is observed, investigators have identified general, chronic undernutrition as a key constraint. For example, a six-week trial of iron supplementation with or without multi-micronutrients in stunted and anaemic children 18-30 mo in Benin observed no effect on appetite, growth or anaemia, despite a small initial increase in haemoglobin of children treated with iron (Dossa *et al.*, 2001). In this case, underlying chronic energy and protein deficiencies were suspected as inhibitors of the response. Allen and colleagues (2000) attributed the lack of haemoglobin response to one year of iron supplementation in children 18-36 mo to "a general syndrome of undernutrition, manifested by poor dietary quality and growth and possibly to vitamin $B_{12}$ deficiency specifically" (p.1493). In these Mexican communities, dietary quality predicted height-for-age z-score (HAZ) and growth; a child's animal source food intake was also positively correlated with haemoglobin response. Taller children had a stronger haemoglobin response to iron supplementation in the first six months.

The synergistic interaction of malnutrition and infection is another well known cause of anaemia, one that is particularly harmful in young children in developing countries. As already discussed, malaria and hookworm, specifically, are associated with an increased risk of moderate and severe anaemia in children U5 and there is evidence for a modifying effect of undernutrition on this relationship. A study in Kenya of children 0-35 mo observed that stunting was associated with significantly increased odds for concurrent malaria, hi-density parasitaemia and severe malarial anaemia; wasting also increased odds of severe malarial anaemia (Friedman *et al.*, 2005b). Verhoef and colleagues (2002) concluded that malaria-associated anaemia, iron demand and inflammation are greater in stunted than in non-stunted children. In their study of Kenyan children 2-36 mo with a baseline prevalence of 39% stunting, 18% malaria parasitaemia and 71% anaemia, stunted children showed a greater malaria-associated

decrease in mean haemoglobin concentration (16.4 g/L; 95% CI 9.3, 23.5) than non-stunted children (8.6 g/L; 95% CI 2.6, 14.6). This remained similar in multivariate regression analysis, controlling for age class and wasting.

Intestinal parasitic infections in children increase the risk of both anaemia and undernutrition. In a study of children 8-14 y in Tanzania, anaemia was strongly associated with the intensity of infection with hookworm and *S. haematobium*; the odds of being anaemic were 1.57 times higher for stunted than non-stunted children (Guyatt *et al.*, 2001). Among preschool children, the effect of helminth infection on child nutritional status is difficult to determine, given that worm infections are associated with poverty and a poor diet, so any harmful effect on growth is likely to be in addition to underlying chronic malnutrition. Mechanisms for intestinal worm infection effect on the nutritional status of children are several: the parasites feed on the child's food intake and internal tissues, causing loss of iron, protein and other nutrients; parasitic damage to the gut surface reduces nutrient absorption; inflammatory responses affect appetite and food intake or modify metabolism and storage of key nutrients such as iron; and there is also a diversion of nutrients in response to the infection (Hall *et al.*, 2008).

Repeated episodes of diarrhoea and other infectious illnesses associated with living in an impoverished and unhygienic environment can also affect nutritional status through their effects on appetite, absorption and metabolic rate (Martorell & Ho, 1984; Brown *et al.*, 1985). HIV infection is also negatively associated with linear growth. A recent review of ten longitudinal studies (eight from sub-Saharan Africa) found that height-for-age Z scores were lower in HIV-infected children versus seroreverters by 0.68 to 1.53 Z at 24 months after birth and these differences persisted through follow-up (Isanaka *et al.*, 2009).

There is also evidence for intergenerational factors that may predispose a child to compromised nutrition and health status. In a nationally representative sample of households in India (n=50 750), maternal height was inversely associated with child mortality, underweight, stunting and anaemia (Subramanian *et al.*, 2009). Women with mild or moderate anaemia prior to conception were more likely to have a low birth weight child; iron deficiency anaemia was associated with a 242-g decrease in

birthweight (Ronnenberg *et al.*, 2004). Maternal malaria and anaemia during pregnancy are also both associated with an increased risk of low birth weight (Rasmussen, 2001). Low birth weight is a risk factor for developing anaemia during infancy; iron stores are correlated with size at birth and low birth weight has been associated with an earlier depletion of iron stores in the newborn and earlier development of iron deficiency anaemia. Placental malaria has been shown to be associated with anaemia in infants at the age of two and six months in Malawi (Reed *et al.*, 1994) and Cameroon (Cornet *et al.*, 1998), respectively. The mother's HIV status alters her risk of malaria during pregnancy. Investigation of the long term implications of low birth weight suggests that it may alter a child's immunocompetence and increase vulnerability to infectious diseases in later life (Raqib *et al.*, 2007), thus further increasing the child's risk for developing anaemia.

### 2.4.10 Summary on aetiology of anaemia

Although much is known about the individual causes of anaemia, much less is known about the interaction between multiple causes occurring simultaneously in the same individuals, whether synergistic or antagonistic. Young children living in sub-Saharan African countries are very likely to be exposed to and suffer from iron deficiency, malaria and other infections simultaneously. Given the level of complexity of this situation, there is little evidence available to date on the individual and multiplicative effects of these causes, except for the fact that single, vertical interventions result in relatively modest impact. Furthermore, there is an added level of complexity in terms of poverty's effects on the community, family and individual response to these factors. For example, the health-seeking behaviour of poor people who become ill differs from that of wealthier individuals. Poor people are less able to mobilise resources rapidly, so they delay seeking treatment and many will first consult traditional healers or treat themselves with drugs from local shops in an effort to save money. Delays in diagnosis and treatment are associated with worse morbidity and mortality (Bates *et al.*, 2004a). Thus it is essential to understand the broader determinants of anaemia in addition to the direct, biological determinants.

## 2.5 Consequences of anaemia

The full extent of the physical, social and psychological consequences of anaemia in young children is yet to be understood, but current evidence suggests that its effects are broad and extend beyond the short-term, especially when anaemia occurs during the early years of child development. The Global Burden of Disease estimates 21,000 deaths and 596,000 disability adjusted life years (DALYs) lost each year among children U5 are attributable to the high prevalence of IDA in sub-Saharan Africa (Stoltzfus *et al.*, 2004b). The biggest challenge in assessing and quantifying the effects of anaemia is the complex aetiology of anaemia, as discussed above. Controlling for environmental factors is important to establish causality, since environmental disadvantage often co-occurs with undernutrition and morbidity; however, only animal models have been able to do so adequately (Lozoff, 2007). Studies on the effects in children have focused on anaemia associated with malaria and iron deficiency, primarily. The following paragraphs present the evidence for effects on child mortality and various aspects of child development.

### 2.5.1 Child mortality

Strong epidemiological evidence exists for severe anaemia increasing mortality risk. A review of the evidence in 2001 found increased mortality rates in children with severe anaemia (Hb <50 g/L) and estimated that the mortality among children due to malarial severe anaemia was at least double that for iron deficiency severe anaemia (Brabin *et al.*, 2001). Severe anaemia contributes to between 17% and 54% of malaria-attributed mortality in children U5 (Obonyo *et al.*, 2007). Recent studies in Malawi and Uganda have highlighted the contribution of HIV infection to severe anaemia and its associated outcomes in young children. Using a case control study design with children 6-60 mo presenting with severe anaemia (Hb <50 g/L) in Malawi, the authors reported that HIV infection and not malaria was the most important risk factor for recurrent severe anaemia and death during the 18-mo follow-up period (Phiri *et al.*, 2008). Cases had much higher mortality rates, both in-hospital and during 18 months of post-discharge follow-up, than hospital or community controls (post-discharge all cause

mortality 12.6% in cases vs. 2.9% in hospital controls and 1.4% in community controls). A prospective cohort study of children with severe malarial anaemia requiring transfusion in Uganda observed that those with HIV infection suffered higher all-cause mortality and malaria-related mortality than HIV-uninfected children (Malamba *et al.*, 2007).

Few studies are available to assess the evidence for increased risk of mortality among children with mild to moderate anaemia (Brabin *et al.*, 2003). A study in Uganda found an increased risk of mortality associated with moderate anaemia (Hb <90 g/L) among HIV-infected children followed from age 9 to 36 mo (Clark *et al.*, 2002). Anaemia suggestive of iron deficiency (Hb <85 g/L and hypochromic microcytosis) but not anaemia alone (Hb <85 g/L) was significantly associated with mortality in the first two years of life (hazard ratio 1.99; 95% CI 1.06, 3.72) among children born to HIV-infected mothers in Dar es Salaam, Tanzania, regardless of the child's HIV status (Chatterjee *et al.*, 2010). In a rural community setting in Gambia, Ghattas et al. (2003) looked at the relationship between haemoglobin concentration and child deaths using a case-control study of children aged 1 mo to 15 yrs (n=403); their study found no evidence of lower haemoglobin in children who died vs. those who survived, except for during the last week of life.

### 2.5.2 Cognitive and physical development

The adverse effects of iron deficiency, iron deficiency anaemia and anaemia on various aspects of child development are well-documented, with the bulk of evidence pointing to a critical role of adequate iron in early childhood. Rodent models with experimental designs have demonstrated that IDA during the "brain growth spurt" period (gestation/lactation) alters brain metabolism and neurotransmission, disrupts myelination and alters gene and protein profiles (Lozoff, 2007). Evidence from studies of infants 6-24 mo with IDA suggests these alterations are associated with poorer cognitive, neurophysiological, motor and social-emotional development (Lozoff, 2007). Among children 36-71 mo in Ecuador, a one-standard deviation increase in haemoglobin levels was associated with an increase in the child's cognitive development test score of 1.7 points, independent of household socioeconomic status or

parental education (Paxson & Schady, 2007). Anaemia is associated also with delayed motor development; anaemic children in Tanzania and Nepal were less likely to be walking unassisted (Kariger *et al.*, 2005; Siegel *et al.*, 2005). Physical activity has also been shown to be reduced in young children with iron deficiency (Olney *et al.*, 2007; Aburto *et al.*, 2009) and in those with anaemia (Olney *et al.*, 2007), an effect that is likely to impact a child's exploration of the physical and social environment, ultimately influencing both cognitive and social-emotional development. In the Zanzibar study, among children who had attained the motor developmental stage of walkers, those with Hb <80 g/L spent 65% less time in motor activity than those with Hb ≥110 g/L (Olney *et al.*, 2007). IDA also has behavioural and affective effects in older preschoolers, with anaemic children 47-69 mo displaying less social looking toward mothers and being slower to display positive affect and touch new toys for the first time (Lozoff *et al.*, 2007).

The timing, duration and degree of severity of iron deficiency and anaemia appear to mediate their effects (Lozoff, 2007). However, longer term effects are also evident, with evidence of a causal relationship between IDA in early childhood and measures of intelligence in mid-childhood, with an estimated decrease in intelligence quotient of 1.73 points for each 10 g/L decrease in haemoglobin (Stoltzfus *et al.*, 2004b). Anaemia in infancy was associated with special education placement at 10 y, based on criteria used for mild or moderate mental retardation in Florida (Hurtado *et al.*, 1999). There is also evidence of cognitive and behavioural effects into adolescence among those who were iron deficient as children (Lozoff, 2007).

Increased attention is being given to iron deficiency and anaemia during the prenatal and foetal period, in terms of its effects on child health and development. Maternal anaemia is associated with adverse birth outcomes, including preterm birth (Stoltzfus *et al.*, 2004b) and low birth weight (Stekedee et al. 1996). Severe maternal IDA threatens foetal iron stores and puts children at risk for earlier onset of iron deficiency and its associated adverse effects on brain development (Lozoff, 2007). In a study of Chinese women, preconception anaemia was associated with reduced infant growth and increased risk of adverse pregnancy outcome (Ronnenberg *et al.*, 2004).

Beyond the personal and public health implications of the above-mentioned adverse effects of anaemia in early childhood, there is a quantifiable reduction in the future productivity of these children. Based on the evidence on the cognitive deficits associated with IDA in childhood and the effect of cognitive achievement on earnings, Horton and Ross (2003) estimated that childhood anaemia is associated with a drop in wages in adulthood of 2.5% and these losses ultimately exceed those associated with the lower physical productivity in adulthood.

Finally, there is no doubt ta large economic and social cost of childhood anaemia, whether this is quantified in terms of the losses in human capital or the heavy burden that it adds to the public health system.

## 2.6 Public health interventions to address anaemia

Based on the growing understanding of the causes and consequences of anaemia in different contexts and target populations, a wide range of public health and nutrition interventions have been developed and tested for their efficacy in reducing anaemia. These interventions are designed to reduce exposure to risk factors for anaemia or to minimize the impact of exposure on health outcomes, including anaemia. In some cases, the effectiveness of these interventions to reduce anaemia in real-life settings has also been demonstrated. The following paragraphs describe the evidence available for these interventions, with a focus on those that have demonstrated impact on anaemia among young children in developing country contexts.

### 2.6.1 Nutritional improvement

A wide variety of interventions have been developed to improve nutrient intake and bioavailability in populations. The most common include the use of micronutrient supplements, fortificants or additives to food such as sprinkles or spreads, and dietary diversification and modification. Although much of the research to date has focused on addressing iron deficiency in populations with high levels of anaemia, there is growing interest in the last decade in developing interventions to address multiple micronutrient deficiencies simultaneously, since there is increased understanding that correcting

nutrient deficiency is only fully achieved when all deficiencies are addressed. This holds promise for anaemia control among children in contexts where diets are inadequate in several micronutrients and infectious diseases further limit the body's ability to maintain adequate hematologic status. In addition, increased focus is being given to earlier intervention to enhance the prevention of anaemia. Effective intervention in the prenatal months and first two years of a child's life are expected to prevent the observed decline in iron stores and increase in anaemia and stunting that develop during this period.

#### 2.6.1.1 Micronutrient supplementation

In 2008, economists in the Copenhagen Consensus stated that providing micronutrient supplements to preschool children in developing countries is "the world's best investment", with very high benefits compared to costs. While fortification may have a lower unit cost for delivery than supplementation and currently is being scaled up in many developing countries, coverage of many vulnerable populations remains problematic (Horton *et al.*, 2008). Supplementation continues to be an important intervention where specific sub-populations are targeted and/or the micronutrient is more costly. In the efforts to address anaemia, supplementation with iron, vitamin A and multiple other micronutrients has achieved a broad range of results, as discussed in the following paragraphs.

##### *2.6.1.1.1 Iron supplementation*

Iron supplementation has been the most widely used strategy globally for the treatment and prevention of anaemia, given that an estimated 50% of anaemia in the world is caused by iron deficiency (Allen, 2002; Stoltzfus *et al.*, 2004b). Iron supplements are used for both therapeutic and prophylactic purposes. International guidelines (WHO/UNICEF/INACG) recommend universal, untargeted iron supplementation for young children where iron-fortified complementary foods are not widely and regularly consumed (Stoltzfus & Dreyfuss, 1998). In these settings, infants should routinely receive iron supplements in the first year of life, starting at two months of age for those with low birth weight and at six months of age for all others. Where the prevalence of anaemia in young children is 40% or higher, iron supplementation is

recommended to continue through the second year of life and also be given in three-month duration to children 2-5 y (WHO/UNICEF/UNU, 2001). The recommended daily dosage is 12.5 mg iron plus 50 µg folic acid for children 6-24 mo and 20-30 mg iron for children 2-5 y. However, there are concerns about the safety and efficacy of iron supplements for young children in contexts where frequent illness and malaria are prevalent (Stoltzfus *et al.*, 2007).

The potential benefits and risks of iron supplementation have been debated for many years. Given the difficulty in changing dietary intake, iron supplementation is perceived as a viable short-term strategy to address iron deficiency in all target groups. Due to the high iron requirements associated with growth, early childhood is a particularly important period in which to ensure adequate iron intake. Among children U5 in resource-poor settings, iron supplementation has particular appeal due to the low quantity and diversity of foods consumed by young children and the difficulty of increasing intake of more expensive sources of bioavailable iron (Mora, 2002). In terms of risks, an overabundance of iron may catalyze the generation of free radicals that cause oxidative damage to tissues, interfere with absorption of other nutrients and support the growth and proliferation of invading pathogens (Iannotti *et al.*, 2006). In malaria-endemic contexts, there is concern that providing oral iron to children at risk for malaria infection may provide the parasite with an advantage, since the body's normal response to malarial infection is to sequester iron (Prentice *et al.*, 2007a). Furthermore, although malaria is associated with an increased risk of anaemia, often severe anaemia, the role of iron supplementation in the treatment of anaemia after acute malaria is still unclear since the haemoglobin response to supplementation is influenced by both the direct inflammatory effect of malaria on iron absorption and pre-existent iron deficiency (Prentice *et al.*, 2007b).

Until recently, the benefits of iron supplementation were believed to outweigh the risks of adverse effects in regions with endemic malaria, based on a review of 13 randomized, controlled clinical trials (INACG, 1999). A subsequent trial also found low-dose iron supplementation alone (without folic acid) for one year among children 4-71 mo in Zanzibar was not associated with any malarial infection outcome in any season

or age subgroup (Mebrahtu *et al.*, 2004). However, international iron supplementation guidelines have been reviewed recently (WHO, 2006b), in light of new evidence from two large RCT (WHO, 2006b). Results from a trial in Zanzibar, Tanzania showed an increase in morbidity and adverse events, including hospitalizations and mortality, among children given iron and folic acid (IFA) supplements compared to those receiving a placebo (Sazawal *et al.*, 2006). The IFA treatment group had a 16% increase (95% CI 0, 34%) in serious malaria leading to hospitalization or death and a 32% (95% CI 2, 70%) excess risk for cerebral malaria. These adverse effects appeared to be mainly attributable to malaria in a population where *P. falciparum* malaria transmission was intense and malaria control efforts inadequate (Stoltzfus *et al.*, 2007). In contrast to these findings, results from a sister study in Nepal, a context with high infectious disease rates but no malaria, showed no adverse effects of IFA supplementation on morbidity or mortality (Tielsch *et al.*, 2006). In a substudy of the Zanzibar trial, analysis of subgroup effects showed that IFA supplementation compared to placebo was of great benefit to children who were iron deficient or anaemic at baseline, in terms of experiencing large and statistically significant reductions in total hospitalizations plus mortality and malaria-related adverse events (Stoltzfus *et al.*, 2007). Based on these results, recommendations for contexts where there is a high prevalence of malaria and infectious diseases now advise targeting IFA supplementation to children who are anaemic and at risk of iron deficiency (WHO, 2006b). Concurrent protection from malaria and other infectious diseases is also recommended for supplemented children, specifically through prevention (e.g. use of ITN while sleeping) and effective case management.

Concerns have also been expressed about the negative impact of iron supplementation on growth in iron-replete children (Bhandari *et al.*, 2001). A meta-analysis of studies that enrolled iron-replete participants with a mean initial haemoglobin value >110 g/L found that none of these reported a significant negative effect of iron on growth and three data sets had significantly positive effect sizes for height (one data set) and weight (three data sets) (Ramakrishnan *et al.*, 2004). The authors concluded that targeting all children for iron supplementation is still safe.

Factors associated with iron supplementation efficacy include the dosing regimen and type of iron provided. Although some have advocated for weekly supplementation regimes based on evidence that they may have reduced side effects, lower cost, potential for improved compliance and reduced oxidative stress, and maintenance of iron stores for a longer period, daily regimes are considered optimal for treatment of iron deficiency anaemia (Allen, 2002). When prevention of IDA is the objective, weekly iron supplementation has been shown to be equally effective (Beaton & McCabe, 1999). The form of iron provided in supplements is important from an absorption perspective. Tablets most commonly contain ferrous sulphate (20% iron in the hydrated form) but ferrous fumarate (33% iron) or ferrous gluconate (12% iron) are also used (Allen, 2002). Liquid formulations with the same iron forms are commonly used for young children. Iron absorption from these compounds is reasonable (average relative bioavailability 89-100%, relative to the standard, ferrous sulfate $7H_2O$ (Hurrell, 2002)) and is further influenced by several factors, including whether the supplement is consumed with a meal and the individual's iron status. When iron is combined with other micronutrients in a supplement, absorption is also affected, especially when they contain zinc, calcium or magnesium (Allen, 2002). It is important to ensure that iron supplements are as bioavailable as possible and that they provide the recommended amounts of absorbable iron, since the cost of supplements is low compared to the delivery costs (Allen, 2002).

There is strong evidence for the efficacy of iron supplementation in improving haemoglobin concentrations and reducing the prevalence of anaemia in young children. A recent meta-analysis of the efficacy of iron supplementation in children found an overall mean change in haemoglobin of 7.4 g/L (95% CI 6.1, 8.7), based on results from 55 randomized controlled trials (RCTs) (Gera *et al.*, 2007). Children who were anaemic at baseline showed the greatest increase while those in malaria hyperendemic areas had a lower response. The estimated reduction in anaemia prevalence due to iron supplementation ranged from 49% in malaria nonhyperendemic areas to 22% in malaria hyperendemic areas. An even larger reduction was estimated for moderate/severe anaemia prevalence, ranging from 65% to 34%. An earlier meta-analysis of 21 data sets of iron interventions in children <18 y of age found a significant difference in the mean

change in haemoglobin concentrations between treatment and control groups of 7.8 g/L, an effect size of 1.49 (95% CI 0.46, 2.51) (Ramakrishnan *et al.*, 2004). Iron supplementation also has potential additional benefits beyond impact on iron and haemoglobin levels. One study found that iron supplementation improved vitamin A status (~0.65 µmol/L increase in plasma retinol) in Mexican preschoolers who received 20 mg/day iron (Munoz *et al.*, 2000).

Failure of iron supplementation to improve iron status and haemoglobin concentration may be due to several causes. Besides issues related to improperly designed intervention, such as providing an inadequate amount of iron or for too short a duration, there are several other factors that may limit haemoglobin response (Allen, 2002). High iron requirements during growth periods may explain why iron stores appear to remain naturally very low during the first year of life (Allen, 2002). Other micronutrient deficiencies may also limit haemoglobin response to iron supplementation, even if iron stores are normalized (Allen, 2002). In children with inflammation due to recent or chronic illness, including malaria, an inflammatory-mediated block to iron absorption and utilization limits the erythropoeitic response to additional iron provided in supplemental or dietary form (Nemeth & Ganz, 2006; Prentice *et al.*, 2007b). Level of adherence to iron supplementation treatment regimen has also been shown to result in improved outcomes; adherence to iron and folic acid supplementation higher than the median resulted in a higher treatment response rate of 50% compared to 39% overall (Bhutta *et al.*, 2009).

While significant evidence exists for the *efficacy* of iron supplementation, there is very little published evidence for the *effectiveness* of iron supplementation under normal field conditions. The reality is that few iron supplementation programs for young children have been implemented and even fewer have been evaluated with regard to impact (Gillespie & Allen, 2002; Stoltzfus *et al.*, 2007). One exception to this is Nicaragua where the national Integrated System of Nutritional Surveillance has documented a decrease in the prevalence of anaemia among children 6-59 mo from 33.5% in 2000 to 17.0% in 2004, likely due in large part to a successful national program providing iron supplements to young children through public health services

and national vaccination days (Lutter, 2008). In a review of iron supplementation programs in 57 UNICEF field offices, only 23 included a recommendation for preschool children (Allen, 2002). Although countries are increasingly developing national policy for addressing anaemia in young children, the recent uncertainty around the safety of universal iron supplementation in malaria-endemic settings has resulted in the removal of this intervention as a priority. Finding a cost-effective delivery system and ensuring compliance and sustainability are major challenges for national iron supplementation programs that target children U5 (Allen, 2002). While recent analyses suggest that targeting supplements to iron-deficient children may "increase benefits, decrease risks, save cost, and possibly heighten the awareness of iron deficiency on the part of health care workers and families" (Stoltzfus *et al.*, 2007, p. S582), further research is needed to confirm this.

*2.6.1.1.2 Vitamin A supplementation*

Periodic vitamin A supplementation of children with high-dose vitamin A capsules is seen as a useful public health strategy to improve child survival and decrease the risk of nutritional blindness and morbidity from measles, severe diarrhoea, HIV and, possibly, malaria and intestinal helminths (Villamor & Fawzi, 2005). Given the demonstrated reduction in child mortality and morbidity with vitamin A supplementation (Beaton *et al.*, 1993), the international community has concluded that periodic large dose vitamin A supplementation is a highly cost-effective approach to preventing and treating vitamin A deficiency in young children (WHO/UNICEF/IVACG, 1997). The current international guidelines recommend universal distribution of oral high-dose vitamin A supplements every 4-6 mo, with doses of 100,000 IU for children 9-11 mo and 200,000 IU for children 12-59 mo (WHO/UNICEF/IVACG, 1997). Based on the high prevalence of both vitamin A deficiency and anaemia in many populations, with young children and women of reproductive age at particular risk, vitamin A supplementation may also be useful in increasing haemoglobin levels and reducing anaemia prevalence. Improving vitamin A status may act through several pathways to improve haemoglobin, including improved absorption of dietary iron in the gut, increased resistance to infection that results in

reduced inflammation, and mobilizing iron from existing stores to support increased erythropoeisis (Zimmerman, 2007).

Most clinical trials have demonstrated a haematological effect of vitamin A supplementation in young children, even when given alone (Semba & Bloem, 2002). Trials that have tested daily or weekly small doses of vitamin A among children between the ages of 1-12 y have demonstrated an increase in haemoglobin of ~6-10 g/L among those receiving vitamin A supplementation compared to controls (Mejia & Chew, 1988; Smith *et al.*, 1999; Mwanri *et al.*, 2000). A study in Tanzanian anaemic children 9-12 y found that the effect was greater if iron was given along with vitamin A (Mwanri *et al.*, 2000). Trials using high-dose vitamin A in children have shown mixed effects on haemoglobin. Among children 6-35 mo in Peru, vitamin A supplements (100,000 IU) showed no hematologic benefit after two months (Alarcon *et al.*, 2004). Children 3-6 y in Indonesia also showed no overall haemoglobin effect five weeks after receiving a vitamin A supplement (200,000 IU); however, subgroup analysis showed that vitamin A-supplemented children who were anaemic at baseline experienced a 7 g/L greater increase in haemoglobin compared to anaemic controls (Semba *et al.*, 1992). Significant effects of high-dose vitamin A supplements on haemoglobin have been demonstrated in two studies in Thailand among children 1-9 y, with measures taken at two weeks (Bloem *et al.*, 1990) and two and four months (Bloem *et al.*, 1989) following supplementation. A recent trial in Morocco among children 5-13 y documented the effect of two sequential doses of vitamin A (200,000 IU), showing an increase in haemoglobin of 7 g/L and a lower prevalence of anaemia (38% vs. 59%) in treated children compared to controls (Zimmermann *et al.*, 2006). The results of this study suggest that sequential doses may have cumulative effects. Most recently, a small study among children 2-6 y (n=80) in Venezuela showed that one dose of vitamin A (200,000 IU) alone was associated with a significant increase in haemoglobin of 3 g/L and decreased prevalence of anaemia (from 17.6% to 13.2%) after one month compared to no change in controls (Jimenez *et al.*, 2010).

Studies also have examined the effect of vitamin A supplementation on anaemia in contexts where malaria infection is common and found less evidence for a role of

vitamin A supplementation alone in improving haemoglobin concentrations. A study in Papua New Guinea found that children 6-60 mo supplemented with vitamin A had a 30% lower frequency of *P. falciparum* febrile illness but no significant differences were observed for haemoglobin concentration or prevalence of anaemia for any age group (Shankar *et al.*, 1999). In a Tanzanian study of a clinical sample of preschool children (6-60 mo) followed up for 8 months following discharge, malaria was associated with a four-fold higher risk for developing anaemia; those who also had received a vitamin A supplement at baseline, 4 and 8 mo during follow-up were not protected from developing anaemia (adjusted prevalence ratio 0.86; 95% CI 0.37, 1.99; p=0.73) (Villamor *et al.*, 2000).

Integration of vitamin A supplementation delivery with routine immunization services (e.g. measles vaccine contact for infants 9-11 mo) and special campaigns (e.g. National Immunization Days or Child Health Days/Weeks) has resulted in relatively high coverage globally, with an estimated 72% of children 6-59 mo in developing countries receiving at least one dose in 2007 (UNICEF, 2009). Despite the broad reach of vitamin A supplementation programs in young children across many countries, the effectiveness of these efforts in reducing anaemia has not been evaluated. However, one recent study compared the nutrition and health status of children 12-59 mo in rural areas of Indonesia who did and did not receive vitamin A supplementation through the national program (Berger *et al.*, 2007). Along with better nutritional status and lower rates of diarrhoea and fever, children who received a vitamin A capsule were significantly less likely to have anaemia compared to those who did not (49.2% vs. 54.8%; OR 0.81; 95% CI 0.78, 0.84). The distribution of haemoglobin in children who did not receive a vitamin A capsule was also shifted to lower values compared with children who received vitamin A. Given the cross-sectional design of the study and the lack of adjustment for potential confounders in the analysis of anaemia results, the protective effect for anaemia of participation in vitamin A supplementation programs remains unmeasured.

#### 2.6.1.2 Multiple micronutrient interventions

Although iron supplementation has been the standard approach to addressing anaemia, there is growing evidence that other nutrient deficiencies are also important in the aetiology of anaemia. Early studies tested the added benefit of one or two additional nutrients, such as vitamin A and zinc. In the past decade, an increasing number of researchers have tested whether combining several micronutrients in a single supplement, known as multiple micronutrient (MMN) supplementation, is more efficacious in improving haemoglobin concentrations and reducing anaemia than iron supplements alone.

In addition to MMN tablets, several other modes of administrating MMN have been developed specifically for young children. Also known as home-based fortification, these products are designed to improve micronutrient intake during the complementary feeding period, usually 6-24 mo, which coincides with the period of greatest vulnerability to iron deficiency. Acceptability of these products by caregivers and young children is generally high and side effects are rare (Dewey *et al.*, 2009). Sprinkles are single-dose-sachets containing a powder mixture of microencapsulated ferrous fumarate (12.5 mg) and other micronutrients (e.g. zinc, vitamins A, C and D or folic acid) formulated according to the needs of the target population (Zlotkin *et al.*, 2004). One Sprinkles sachet can be added daily to semi-solid food for young children; both daily and flexible (e.g. 60 sachets over a period of 3-4 mo) administration have been shown to improve haemoglobin levels and reduce anaemia in children 6-24 mo (Ip *et al.*, 2009). Foodlets (e.g. Nutritab) are large tablets made with a high concentration of milk powder that can be crumbled and mixed with complementary foods or fluids appropriate for young children. Foodlets contain MMN and are flavoured to mask the taste of the iron, which is not encapsulated. Both daily and weekly foodlet administration are efficacious in improving infant anaemia and micronutrient status, with daily having a greater effect than weekly frequency (Smuts *et al.*, 2005). Lipid-based nutrient supplements (e.g. Plumpy'Nut, Nutributter) are single-dose packets formulated to include iron and other micronutrients as well as additional energy, essential fatty acids and protein. A fortified lipid-based spread reduced anaemia by 90%

and produced an increase in haemoglobin concentration that was over two times higher compared to the control group among children 3-6 y living in a refugee camp (Lopriore *et al.*, 2004). In a study comparing the effects of Sprinkles, Foodlets and Plumpy'Nut among infants in Ghana, all three products had a similar significant effect at 12 mo on iron status when compared to the placebo group and Plumpy'Nut and Foodlets also had a significant effect on mean haemoglobin levels compared to placebo (Adu-Afarwuah *et al.*, 2008).

The relative effects of MMN compared to iron alone or a placebo have been reviewed by two recent papers, with slightly different approaches. Allen et al. (2009) summarized the relative benefits of providing MMN vs. a placebo or one or two micronutrients (including iron), based on the results from 26 trials that reported effects on haemoglobin and anaemia in children ranging from infants to adolescents. MMN were found to be more effective at increasing haemoglobin compared with a control group, with a mean effect size of 0.39 (95% CI 0.25, 0.53). Some differences in effect were observed across studies. Use of fortified foods (defined as MMN preparations containing >100 kcal/d in energy and macronutrients) was more effective (effect size 0.60; 95% CI 0.32, 0.88) and younger children had a larger increase in haemoglobin due to MMN than older children. Baseline haemoglobin, HAZ and WAZ were not related to the observed effect size. Among the nine studies reporting the change in the prevalence of anaemia, the reduction in anaemia with MMN vs. a non-iron placebo ranged from 10-40%. A greater reduction in anaemia was observed in trials supplying a higher amount of iron per day in the MMN and in populations with a higher baseline prevalence of anaemia.

Gera et al. (2009) also reviewed RCTs that evaluated change in child haemoglobin levels with interventions that included iron and MMN supplementation in comparison to placebo alone or iron alone. Based on 25 trials that compared iron and MMN supplementation to placebo, the pooled weighted mean difference of the haemoglobin change was 6.5 g/L (95% CI 5.0, 8.0; $p<0.001$). A positive effect was more likely among children who were anaemic and stunted at baseline and those who were given only a defined group of micronutrients (zinc, vitamin A, riboflavin, vitamin

B12, folic acid and ascorbic acid). Children living in areas not endemic for malaria also tended to show a more positive effect. However, in the second analysis of 13 studies that compared iron and MMN supplementation to iron alone, the pooled weighted mean difference in haemoglobin was much smaller, 1.4 g/L (95% CI 0.00, 0.28; p=0.044), suggesting that the addition of MMN only marginally improves the haemoglobin response. Following this review, a similar finding was observed in a study comparing MMN to iron/folic acid treatment for severe anaemia among children 6-24 mo in Pakistan (Bhutta *et al.*, 2009). Also published after the review was a study in a malaria-endemic area of Burkina Faso that showed that when malaria management was combined with six months of supplementation for all groups of children 6-23 mo, those receiving MMN showed a 6 g/L higher increase in haemoglobin compared to those receiving iron alone (Ouedraogo *et al.*, 2008). Anaemia prevalence decreased significantly after 12 mo in the groups of South African infants receiving supplements of vitamin A alone (control group) or MMN, but not in the group receiving vitamin A and zinc (Chhagan *et al.*, 2010).

It is important to note that although the addition of MMN may not result in a large added effect on haemoglobin concentration or anaemia reduction, other positive effects of MMN have been shown, including improved child growth and motor development and improved zinc and vitamin A status (Allen *et al.*, 2009). There are still many gaps in our understanding of what nutrients should be included in each context, the appropriate amount to give and possible interactions between micronutrients. One key concern has been the observed negative interaction of iron and zinc when provided together, an area of active research (Fischer Walker *et al.*, 2005; Berger *et al.*, 2006; Olivares *et al.*, 2007).

Evidence for the effectiveness in real-life settings of MMN interventions is growing. The effectiveness of targeted fortification of complementary foods in public health (Lutter *et al.*, 2008) and community-based program settings (Zlotkin *et al.*, 2005; Menon *et al.*, 2007a) has been documented. However, scaling up to national level and ensuring reach to the poorest households remains a significant challenge. In addition, although these interventions are well-designed to reach children under two years of age,

older preschool children (2-5 years of age) are not likely to benefit from fortified complementary foods and therefore continue to be unreached.

*2.6.1.2.1 Micronutrient fortification*

Fortification is the practice of increasing the content of an essential micronutrient in a food so as to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health (Allen *et al.*, 2006). Fortification is highly cost-effective and was the third-ranked solution overall by the Copenhagen Consensus in 2008 as a priority for investment to improve global welfare. Fortification of staple foods such as flour with iron can be done at a cost of only $0.10-0.12 per person per year, with a benefit-cost ratio calculated to be 8.7 (Horton *et al.*, 2008). Large-scale fortification of infant formula and staple foods with iron and other micronutrients is credited with contributing to the dramatic reduction in the prevalence of iron deficiency anaemia among young children in developed countries (Ramakrishnan & Yip, 2002).

In sub-Saharan Africa, micronutrient-fortified staple foods are less likely to be effective in reaching the most vulnerable children, particularly in rural communities where the majority of households produce their own food. In these areas, it is difficult to find an appropriate food vehicle that is widely consumed throughout the year by a large portion of the population at risk of iron and other micronutrient deficiencies. Even when fortified products are available, their higher cost is often prohibitive for economically marginalized households and the bioavailability and amount of iron provided may be insufficient to meet the daily requirements of children U5 (Lutter & Rivera, 2003; Allen *et al.*, 2006). The common use of elemental iron as the fortificant also reduces efficacy due to the low bioavailability of this form of iron. Researchers are actively investigating how to improve iron bioavailability, particularly in cereals high in phytate such as whole maize flour, commonly eaten by poor rural families (Hurrell, 2004; Andang'o *et al.*, 2007).

Increasing the availability and reach of fortified foods targeted specifically for young children appears to be the best way to overcome the challenges of large-scale fortification. Strategies must take into account changing dietary habits during infancy

and childhood, as well as the different nutrient densities required by children at different ages (Ruel *et al.*, 2004). The efficacy, and in some cases effectiveness, of food fortification in reducing child anaemia in developing countries has been demonstrated in programs that distributed targeted cereal-based supplements fortified with iron and other micronutrients (Lopez de Romana, 2000; Rivera *et al.*, 2004; Faber *et al.*, 2005; Lutter *et al.*, 2008) and iron-fortified milk (Olivares *et al.*, 1989; Torrejon *et al.*, 2004; Villalpando *et al.*, 2006b) to infants and young children. Fortification with iron of food (Varma *et al.*, 2007; Arcanjo *et al.*, 2008) and water (Dutra-de-Oliveira *et al.*, 2007) served to older preschool children in daycare centres has also been shown to improve haemoglobin levels and reduce anaemia. In populations where rice is eaten daily by young children in sufficient amounts, the efficacy of rice fortified with iron (using Ultra Rice technology) to improve iron status and reduce anaemia has recently been demonstrated and the authors of this study believe that the high level of iron fortificant used may also be appropriate for the general population (Beinner *et al.*, 2010). Although costly as an intervention, the provision of fortified complementary foods, milk or both as part of social welfare programs in Latin America has demonstrated success in improving haemoglobin levels in children in Mexico and Peru; these foods are widely accepted and consumed by indigenous and urban poor populations (Lutter & Rivera, 2003). The effectiveness of Mexico's national iron-fortified subsidized-milk program in reducing the prevalence of anaemia and iron deficiency after one year in children 12-30 mo has also been documented (Rivera *et al.*, 2010). Although experience with mandatory flour and oil fortification is growing among nations in sub-Saharan Africa, there has been no evaluation to date of the effectiveness of these efforts on the iron or anaemia status of young children.

Bovine haemoglobin concentrate is made from cow's blood and has been used with some success as an iron fortificant for children's food (Allen & Ahluwalia, 1997). A recent trial providing bovine serum concentrate-fortified cereal with or without MMN to infants for eight months found no growth or morbidity effects among children receiving the fortified food; however, children who received the MMN had higher haemoglobin levels and lower rates of anaemia compared to those not receiving any fortificant and those receiving only the bovine serum concentrate-fortified cereal (Begin

*et al.*, 2008). The potential of bovine serum concentrate as an iron-fortificant needs further study in human populations.

#### 2.6.1.3 Other approaches to increase iron intake and bioavailability

Various food-based approaches have been developed in the effort to increase production, availability, intake and absorption of iron and other micronutrients in the diets of children. The main advantage of these strategies is the potential to improve multiple nutritional factors simultaneously and achieve both short-term impact and long-term sustainability, with no risk of antagonistic interactions or nutrient overload (WHO/UNICEF/UNU, 2001). Improving the overall nutritional status of children is also expected to decrease the frequency and severity of illness, another important aetiological factor in childhood anaemia. Furthermore, since food-based approaches focus on improving the overall quality of the diet by increasing fruit, vegetable and animal product intake, these efforts may provide additional health benefits due to increased intake of other nutrients, such as essential fatty acids and phytonutrients, and reduced risk of chronic disease and overweight (Allen, 2008).

However, despite the theoretical potential to ensure adequate nutrient intake through locally available home-prepared foods, analysis of food intake data from infants 6-11 mo in Bangladesh, Malawi and Guatemala showed that protein, fat and energy requirements could be met but micronutrient requirements (especially iron, zinc, calcium and B-vitamins) were unlikely to be provided in adequate amounts (Brown *et al.*, 2002). In a recent effort to develop affordable, locally contextual feeding recommendations for children 9-11 mo in Indonesia, investigators concluded that a diet based on local foods could not provide theoretical iron requirements, even when iron-dense foods were preferentially selected (providing 63% of iron required), and that alternative strategies such as fortification or supplementation are required in order to ensure iron requirements are met (Santika *et al.*, 2009). In general, increased dietary diversity and traditional food-processing techniques have been unsuccessful at completely closing the gap between iron intake and needs, especially in young children.

Promoting the consumption of animal source foods, including meat, organ meats, fish and dairy products, is a logical strategy to improve children's dietary quality and micronutrient status. Traditional diets of low-income families in developing countries tend to be plant-based and have low quantities of animal source foods. In addition to being a good source of protein and energy, animal source foods provide several micronutrients in highly bioavailable forms, including haem iron, vitamin B12, zinc and retinol. Even small quantities of haem iron from meat, poultry or fish in a meal can enhance non-haem iron absorption (Gibson & Hotz, 2001). Research exploring the causal pathway between animal source food availability and nutritional status has found a complex set of factors, including community level factors (e.g. poverty, animal health, land degradation), household factors (e.g. cost of animal source foods, preferential food allocation patterns) and individual level factors (e.g. caregiver perceptions, child care patterns) that limit the consumption of animal source foods and may be useful points for intervention (Gittelsohn & Vastine, 2003; Pachón *et al.*, 2007). For example, children's consumption of animal source foods in Ghana was limited by the small amount used in meals and infrequency of meals containing animal source foods (Colecraft *et al.*, 2006). Caregivers in this context reported that they believed young children have difficulty eating meat and also were unwilling to offer animal source foods to children because it would encourage unrealistic taste preferences and expectations that would not always be possible to meet.

Interventions designed to increase the intake of animal source foods include efforts to promote animal production and aquaculture as well as nutrition education to encourage consumption of the products and ensure that animal source foods are preferentially given to high risk groups, such as children and pregnant women (Gibson & Hotz, 2001). Addressing household purchasing power through income generating activities (Colecraft *et al.*, 2006) and increasing access to refrigeration (Gibson & Hotz, 2001) are alternative means to encourage the purchase and consumption of animal source foods in rural communities. A review of 14 animal production promotion interventions found that while most had a positive impact on production, dietary intake and household income, there was insufficient evidence to determine whether it was an effective means to alleviate undernutrition (Leroy & Frongillo, 2007). Projects that

combined animal production efforts with nutrition education were more likely to achieve improved dietary intake (Ruel & Levin, 2000; Berti *et al.*, 2004).

Increasing iron bioavailability through food processing techniques such as fermentation and germination to reduce phytic acid levels has been tested in countries where whole maize is widely consumed (Gibson & Hotz, 2001). Evidence for the efficacy and effectiveness of enhancing iron absorption through consumption of ascorbic acid with food and reducing intake of iron absorption inhibitors, such as tannins in tea, is limited (Ruel & Levin, 2000). Adding ascorbic acid alone to a whole grain weaning food increased nonhaem iron absorption in adults by 39% whereas adding both ascorbic acid and meat powder improved nonhaem absorption by 2.6 times and increased the total iron absorption by three times that of the basal meal (Hallberg *et al.*, 2003). There is some evidence that eating food prepared in iron pots increases the haemoglobin concentration of anaemic/iron deficient individuals; however, results of trials to date are not conclusive and poor adherence to using iron pots appears to be a key constraint (Geerligs *et al.*, 2003).

Decreasing vitamin A deficiency through increased dietary intake of vitamin A-rich foods also has the potential to reduce anaemia rates, similar to findings from supplementation trials. Studies in adults have shown improved haemoglobin levels when β-carotene-rich foods were consumed (Ncube *et al.*, 2001; Agte *et al.*, 2006) but studies among preschool children have shown mixed results. There was no improvement in haemoglobin concentration among anaemic preschoolers in Ghana who were fed dark green leafy vegetables, despite an observed increase in serum retinol concentration (Takyi, 1999). Anaemic preschoolers fed a β-carotene-rich rice preparation in Vietnam showed improved serum retinol and haemoglobin concentration compared to controls (Vuong le *et al.*, 2002).

Few studies have been published on the efficacy of dietary strategies to reduce anaemia or iron deficiency in young children. The addition of fish powder to fermented maize porridge or cereal-legume blend given to Ghanaian infants from 6 to 12 mo of age nearly doubled the iron content of these foods but did not improve infant iron status (Lartey *et al.*, 1999). In New Zealand, researchers found no evidence for an effect of a

moderate increase in red meat consumption on the prevalence of suboptimal iron status or haemoglobin concentration among healthy nonanaemic children 12-24 mo (Szymlek-Gay *et al.*, 2009). However, fortified milk consumption increased mean serum ferritin concentration by 44% from baseline levels in these children. In a study of Kenyan school children, neither the children receiving meat nor those receiving milk supplements in a daily meal showed any change in iron or anaemia status after one year of intervention, despite the fact that 49% were anaemic at baseline overall (Siekmann *et al.*, 2003).

A community-based dietary diversification and modification intervention in rural Malawi utilized several of the above strategies to improve the content and bioavailability of iron and other micronutrients in the local diet (Gibson *et al.*, 2003). The strategies included 1) increasing production and consumption of micronutrient dense foods (including meat, poultry, whole dried fish with bones and vitamin A-rich fruits); 2) incorporating micronutrient absorption enhancers in the diet; and 3) promoting germination, fermentation and soaking to reduce phytate content of maize and legumes. After six months, comparison of dietary intake among children 30-90 mo from intervention and control communities revealed that the intervention had effectively decreased phytate intake and improved intake of zinc and other micronutrients. Although their dietary iron intake was not higher, intervention children consumed more diverse diets and animal source foods accounted for a higher proportion of their total energy and protein intake compared to control children. Analysis of the effects of the intervention on anaemia and morbidity showed that mean haemoglobin was higher (107 vs. 102 g/L, $p<0.01$), anaemia was lower (62 vs. 80%) and overall morbidity (fever, diarrhoea, respiratory infections) was lower in intervention children compared to controls (Yeudall *et al.*, 2002). The authors suggested the positive impact of the intervention on anaemia levels was due to the increased bioavailability of iron as well as increased intake of other nutrients (Yeudall *et al.*, 2002; Gibson *et al.*, 2003).

Homestead food production programs in Bangladesh have been evaluated for their effect on household food production and consumption of micronutrient-rich foods (Bushamuka *et al.*, 2005). Recently, a similar program in Cambodia that focused on

increasing production and consumption of vitamin A-rich fruits and vegetables, as well as small animal production, was evaluated for its effects on production, dietary diversity and health and nutrition outcomes (Olney *et al.*, 2009). Greater household production of fruits and vegetables was associated with greater household dietary diversity, which was in turn associated with dietary diversity among mothers and children. However, dietary diversity was not associated with other maternal and child health and nutrition outcomes. Among children U5, there were no statistically significant differences in anaemia or mean haemoglobin between the intervention and control groups and there appeared to be some deterioration in both indicators and in both groups between baseline and endline.

Nutrition education interventions can be effective in changing the way caregivers give food to young children, increasing dietary intake and improving child growth. Results from a randomized trial in Peru where nutrition education was delivered through government health facilities to women with infants showed significantly higher intakes of energy from animal sources in the intervention group compared to the control group at age 15 and 18 mo, but mean total iron intake was not significantly higher when adjusted for socioeconomic variables and below recommended intakes for both groups (Penny *et al.*, 2005). A randomized trial comparing the effect of nutrition education emphasizing iron-rich foods, weekly iron supplementation (20mg/d), education plus iron supplementation and placebo among children 9-36 mo in India found that mean haemoglobin was higher in all 3 intervention groups (by 6-8 g/L), compared to the placebo group, and mean ferritin concentrations were higher in the two groups receiving nutrition education (Kapur *et al.*, 2003).

A relatively new area of research is biofortification, which is the development of plant breeds with higher iron or other micronutrient content. It is estimated that the iron content of rice may be increased by 100-167% which translates into 0.6-1.0 mg additional iron for 200 g rice consumed per day, and that of wheat by 20-60% (Stein *et al.*, 2008). A comparison of haemoglobin synthesis in iron-deficient pigs found that pigs fed biofortified beans with rice gained more haemoglobin iron than pigs on a standard beans and rice diet (Tako *et al.*, 2009). Recent efficacy studies in humans have

demonstrated that biofortification can have an impact on nutritional status. One 9-mo trial with high-iron rice in the Philippines has shown positive effects in terms of increased iron intake in women (Haas *et al.*, 2005). Studies in South Africa and Mozambique have also shown improvements in vitamin A status with consumption of orange-fleshed sweet potato that is high in beta-carotene (van Jaarsveld *et al.*, 2005; Low *et al.*, 2007). Effects on anaemia in young children have not yet been assessed.

## 2.6.2 Disease control

Given the significant contribution of infections and inflammation to child anaemia, efforts to prevent and control anaemia in populations must address the factors contributing to child morbidity. Disease control efforts include those that reduce exposure to pathogens through preventive measures and those that ensure timely and effective treatment of illness when it occurs.

### 2.6.2.1 Malaria prevention and treatment

Efforts to control the effects of malaria on anaemia in preschool children have focused on preventing exposure to infective mosquito bites, intermittent preventive treatment (chemoprophylaxis) and ensuring timely, appropriate treatment of malaria episodes to clear parasites from the blood.

Insecticide treated nets (ITNs) and curtains provide both a physical barrier for humans from mosquito bites and kill mosquitoes in the area, reducing overall transmission levels. Indoor residual spraying (IRS), which involves applying a long-lasting insecticide to the inside walls of rooms where people sleep to kill mosquitoes when they rest on the walls, also reduces malaria transmission. Current recommendations for malaria-endemic settings are that all people should regularly sleep under an ITN, with specific priority given to young children and pregnant women (RBM, 2010). ITNs are highly efficacious in reducing childhood mortality and morbidity from malaria, with an estimated 50% reduction in the incidence of malarial episodes in areas of stable malaria (compared to no nets) and an improvement in the average haemoglobin level in children by 1.7% packed cell volume (Lengeler, 2004).

The effectiveness of ITN programs has also been demonstrated; an evaluation of the effects of a large-scale ITN social marketing program in Tanzania was carried out over a period of two years (Abdulla *et al.*, 2001). In parallel with a rapid increase in ownership of bed nets and stable rate of malaria transmission, the prevalence of anaemia among children under two years of age decreased from 49% to 26% (mean haemoglobin increased from 80 to 89 g/L) and parasitaemia decreased from 63% to 38%. The authors estimated that ITNs had a protective efficacy of 62% and 63% on the prevalence of parasitaemia and anaemia, respectively. More recently, an evaluation in three districts of Togo of the short-term impact on U5 anaemia and malaria morbidity of mass distribution of free long-lasting ITNs showed that ITN ownership increased from <1% to >65%, reported ITN use by children during the previous night ranged from 36-81% and the overall prevalence of moderate-severe anaemia (Hb <80) was reduced by 28% (prevalence ratio 0.72, 95% CI 0.62-0.84) among children 0-59 mo (Terlouw *et al.*, 2010). Although clinical malaria was also reduced, no change was observed in parasitaemia levels in this period. Paradoxically, the district with the highest malaria burden and best ITN coverage showed no reduction in anaemia or malaria morbidity among any age group.

Strategies to increase ITN coverage have ranged from commercial market promotion, social marketing programs with subsidies/vouchers (Schellenberg *et al.*, 1999; Mushi *et al.*, 2003) and provision of free ITNs to vulnerable groups through community distributions or primary care clinics (Grabowsky *et al.*, 2005; Grabowsky *et al.*, 2007). A review of ITN coverage data from 40 malaria-endemic countries in Africa found that although coverage among children U5 increased from 2% in 2000 to 19% in 2007, 33 countries were estimated to have ITN coverage of less than 40% in 2007 (Noor *et al.*, 2009). Although these authors observed relative equity in coverage between children living in the most poor areas compared with those in the least poor (21% vs. 16%, p=0.275), others have observed marked inequity in net ownership and malaria outcomes. For example, in Tanzania, where families have benefited from national ITN social marketing efforts as well as periodic free distribution through local clinics, although 71% of children U5 reportedly slept under a bed net the previous night (54% under ITN), the ratio of household ownership of any net was 0.58 between the poorest

and least poor (Bernard *et al.*, 2009). Rapid diagnostic test results for malaria showed that individuals from the least poor households also had a significantly lower risk of malaria compared to the poorest households (OR 0.49, 95% CI 0.35-0.70) even when adjusted for use of bed net.

Another malaria prevention strategy is intermittent preventive treatment (IPT) which involves providing a full treatment dose of an antimalarial drug, regardless of the individual's parasitaemia status, at specified intervals. Initially promoted for malaria prevention during pregnancy, recent trials have shown the efficacy of this strategy in infants and children as well (Munday, 2007). A systematic review comparing antimalarial drugs given at regular intervals (prophylaxis or intermittent treatment) with placebo or no drug in children under six years of age living in malaria-endemic areas found that children receiving prophylaxis or intermittent treatment had fewer clinical malaria episodes and severe anaemia was less common (RR 0.54, 95% CI 0.42, 0.68) (Meremikwu *et al.*, 2005). In two recent controlled studies of the impact of IPT among preschool children, intermittent malaria treatments reduced the annual incidence rate of clinical malaria by 43% in Mali (Dicko *et al.*, 2008) and 86% in Senegal (Cisse *et al.*, 2006).

Prompt treatment**,** preferably within 24 hours of fever onset, of clinical malaria episodes with an effective antimalarial agent is essential for preventing life-threatening complications and reducing the health impact, including the risk of developing severe anaemia. Effective treatment of malaria in children clears parasites from the body and enables hematologic restoration (Ekvall, 2003). Monitoring data from African nations suggest that many children with fever are treated at home and less than 60% are treated in a health facility (RBM, 2010). A longstanding lack of malaria diagnostic capability has also hindered effective treatment efforts in the majority of rural African areas. Given concerns with growing resistance to chloroquine as a first-line treatment for malaria, recent policy has shifted to use of artemisinin-based combination therapy (ACT) to ensure and sustain effectiveness. Interventions to improve child malaria treatment practices have targeted health facility and community/household levels. IMCI has been shown to improve case management at health facilities in Tanzania (Armstrong

Schellenberg *et al.*, 2004) and Bangladesh (Arifeen *et al.*, 2009) but the indirect effect of these improvements on child anaemia have not been measured. The WHO has promoted home-based management of malaria as a major strategy to improve access to antimalarials in Africa, encouraging presumptive treatment of febrile children at home with antimalarial drugs distributed by trained members of the community (WHO, 2005b). The key components of this strategy include training of community members, including primary caregivers, how to recognize malaria episodes and ensuring a local source of appropriate antimalarial drugs (often pre-packaged for improved compliance) for presumptive treatment. Current evidence demonstrating the health benefit of home- and community-based presumptive treatment of fever with antimalarials is limited (Hopkins 2007); some trials have shown reduced severity of malaria morbidity (Sirima *et al.*, 2003) and mortality (Kidane & Morrow, 2000) but effects on anaemia have not been evaluated. In 2010, revised malaria treatment guidelines were released which recommend parasitological confirmation by microscopy or rapid diagnostic tests before treatment of suspected malaria cases (WHO, 2010). A recently published controlled trial from Zambia has demonstrated the feasibility for trained community health workers to use rapid diagnostic tests and reduce the overuse of ACT for treatment of child fevers (Yeboah-Antwi *et al.*, 2010).

Improved micronutrient status through nutrition interventions has also been shown, in some but not all cases, to reduce the risk of malaria episodes and malaria-associated anaemia (Shankar *et al.*, 2000; Fischer Walker & Black, 2004). For example, vitamin A supplementation alone in Papua New Guinea (Shankar *et al.*, 1999) or with zinc in Burkina Faso (Zeba *et al.*, 2008) reduced the incidence of uncomplicated malaria by about one-third among young children. However, a vitamin A supplementation trial in Ghana did not find this malaria protective effect (Binka *et al.*, 1995).

In a review of 29 community-based controlled studies in malaria-endemic parts of Africa, Korenkomp et al. (2004) estimated the effect of malaria interventions on haemoglobin in children U5; a median reduction in parasite prevalence of 42% was associated with a mean estimated increase in haemoglobin of 7.6 g/L (95% CI 6.1, 9.1). A recent evaluation of a large-scale malaria control program on Bioko Island, Equatorial

Guinea, has demonstrated the potential effectiveness of an integrated package of interventions (Kleinschmidt *et al.*, 2009). Over a four-year period, the program provided a comprehensive IRS program, free ACT as first-line treatment for malaria in children <15 y and pregnant women, training of doctors and nurses in case management according to the national treatment policy, IPT for pregnant women, universal door-to-door campaign to distribute and hang free long-lasting ITNs to cover all sleeping areas, and a comprehensive information, education and communications campaign to promote adherence to all components of the intervention. By the fourth year, over 95% of children 2-5 y were living in an IRS-treated house or sleeping under an ITN. Between baseline and year four, reductions were observed among children 2-5 y in prevalence of infection with *P. falciparum* (OR 0.31, 95% CI 0.2, 0.5) and anaemia (OR 0.11, 95% CI 0.07, 0.18). In addition, under-5 mortality fell from 152 to 55 per 1,000 births (hazard ratio 0.34; 95% CI 0.23, 0.49). Although no control group was assessed, there is a high level of plausibility that the effects observed could be largely attributed to the program, given the sharp simultaneous decline in multiple measures of malaria transmission during the intervention period and no evidence of other major concurrent child health interventions or rapid economic development on the island.

#### 2.6.2.2 Parasite prevention and treatment

Intestinal parasites have proven to be very difficult to eradicate in communities where poverty and inadequate water and sanitation prevail because of their high transmission potential (Brooker *et al.*, 2004). In the absence of marked improvements in economic development, minimal impact has been achieved by efforts to improve sanitation and provide health education. Therefore, reducing morbidity through mass deworming treatment programs has become the primary strategy in most affected populations (Brooker *et al.*, 2004). It is recommended that anaemia control programs include annual preventive anthelminthic chemotherapy where prevalence of soil-transmitted helminth infection is greater than 20% among school-age children; twice a year chemotherapy is recommended for high risk communities where infection is greater than 50% (WHO, 2006a). These guidelines recommend treatment of all school-age children as well as preschool children, women of reproductive age and adults at high

risk in certain occupations.[4] A recent meta-analysis evaluated the efficacy of anthelminthic drugs on haemoglobin in children and adults; deworming was associated with a mean change in haemoglobin of 1.71 g/L (95% CI 0.70, 2.73) overall (Gulani *et al.*, 2007). Among children, the average estimated reduction in the prevalence of anaemia with deworming ranged from 4 to 21%.

Although the treatment of hookworm infection reduces blood loss, improves iron status and reduces risk of developing IDA (Crompton & Nesheim, 2002), improving iron intake may be a necessary adjunct therapy, given the prevalence of iron deficiency among populations where these infections are common (De Silva, 2003). Impact of iron supplementation or fortification and deworming is greater when combined (Stoltzfus *et al.*, 1997a; Gillespie & Johnston, 1998). Deworming is also associated with other positive outcomes in children, such as improved appetite and growth (Stoltzfus *et al.*, 2004a). A recent evaluation of the effectiveness of delivering anthelminthic treatment to children 1-7 y as part of a community child health program in Uganda found that the intervention increased weight gain by about 10% above expected weight gain when treatments were given twice a year (Alderman *et al.*, 2006).

Improving household access to potable water sources, use of sanitary latrines/toilets and personal hygiene promotion are essential to reducing environmental contamination and exposure to infective agents. While deworming reduces the intensity and morbidity associated with helminth infections and reduces transmission, improvements in environmental factors and sanitation are required in order to prevent re-infection (Crompton & Nesheim, 2002). Interventions that promote sanitation and health education have been shown to reduce the prevalence and intensity of helminth infections (Asaolu & Ofoezie, 2003). Water, sanitation and hygiene interventions also have been shown to decrease child malnutrition in Peru, an effect that may be mediated primarily by preventing diarrheal disease (Checkley *et al.*, 2004).

[4] Adults with occupations involving contact with infested water, such as fishermen, farmers, irrigation workers, or women in their domestic tasks are at increased risk of schistosomiasis. Tea pickers and miners are considered at increased risk of helminthiasis.

### 2.6.3 Multi-sectoral anaemia control programs

Given the complex, multifactorial nature of anaemia, multiple interventions are expected to have a greater effect than any single intervention. Furthermore, many would argue that child anaemia, like child undernutrition, is "rooted in poverty, food insecurity, gender inequity, and lack of access to health and other services" (Leroy *et al.*, 2009). The long-term impact and sustainability of anaemia control efforts will depend, in large part, on the ability to address factors related to the global context in which anaemia occurs. In malaria-endemic regions of Africa, it is proposed that anaemia "…is best tackled by means of an integrated, non-disease-specific approach" (Crawley, 2004, p.30), with interventions targeted to groups with the highest risk, including pregnant women and young children. The estimates published recently in the Lancet Series on Maternal and Child Undernutrition suggest that if a group of effective, targeted nutrition and health interventions [5] were implemented at scale to these two target groups, undernutrition-related mortality and disease burden could be reduced by 25% in the short term (Bhutta *et al.*, 2008a). The next section looks at the evidence for the efficacy and effectiveness of multiple, integrated interventions to reduce anaemia in children U5.

#### 2.6.3.1 Efficacy of multi-sectoral anaemia control interventions

To enhance efficacy of interventions on anaemia control in children, researchers have most commonly tested the integration of micronutrient supplementation and public health interventions such as malaria or other parasitic infection control. Most of these trials have been implemented under controlled conditions for short periods of time (≤1 y). It is important to note that relative efficacy is highly dependent on the specific aetiology of anaemia and the current nutritional and health status of the children targeted with the intervention. Comparisons of effects across contexts and age groups must be done with caution.

[5] The targeted nutrition interventions recommended include breastfeeding promotion, behaviour change and communication strategies to improve complementary feeding practices, supplementation and food fortification to improve micronutrient status, health interventions aimed at reducing infectious diseases among infants and young children, and the effective management of severe acute malnutrition.

Combining iron supplementation with public health interventions such as deworming and malaria chemoprophylaxis or prevention through use of ITNs has been shown to be more effective in reducing anaemia than these interventions alone, with few exceptions. In a recent meta-analysis of anthelminthic treatment effects, iron supplementation as a co-intervention with deworming was a significant predictor of a positive effect on haemoglobin levels in children (19.1 g/L; 95% CI 2.2, 36.2) (Gulani *et al.*, 2007). However, where hookworm is not prevalent in young children, anthelminthic treatment in combination with iron supplementation has not resulted in additional improvement in haemoglobin status (Palupi *et al.*, 1997). Based on a placebo-controlled RCT among infants in Tanzania, a combination of daily iron supplements and weekly malaria chemoprophylaxis was more effective in reducing the incidence of severe anaemia (69% reduction) than either iron alone (32% reduction) or chemoprophylaxis alone (60% reduction) (Alonzo Gonzalez *et al.*, 2000). Another study in Tanzania found that malaria case management and multiple micronutrient (including iron) supplementation synergistically improved haemoglobin response in children 5-36 mo over an extended period (Ekvall *et al.*, 2000).

In terms of the treatment of anaemic children, the use of iron supplements in combination with other micronutrients and antimalarial or deworming medicines has also been explored. Combining iron supplements with an effective anti-malarial therapy has been shown to be an effective strategy for promoting haematological recovery after an attack of acute malaria in Gambian children (age 6 mo to 9 y), with an additional increase in haemoglobin among iron supplemented children of just under 10 g/L at 28 days that was retained for several months after the malaria attack (van Hensbroek *et al.*, 1995). Treatment response among severely anaemic (Hb <70 g/L) children 6-24 mo in Pakistan was similar among groups receiving only iron and folic acid supplements compared to those also receiving multivitamins or mebendazole (Bhutta *et al.*, 2009).

#### 2.6.3.2 Effectiveness of multi-sectoral anaemia control programs

Although the integrated, multiple intervention strategy tends to be accepted more in principle than in practice and control strategies tend to focus on interventions where substantial resources are available, there is growing recognition that single, vertical

strategies will not be effective in fully addressing anaemia and different contexts will require different combinations of interventions (Lynch *et al.*, 2007b). As a result, donors, non-government organizations and national governments are looking to nutrition and public health program designs that have the potential to deliver a set of integrated interventions to vulnerable children and women at scale. The following paragraphs provide a summary of the evidence to date on the effectiveness of multi-sectoral programs in reducing child anaemia levels.

The Good Start in Life Program was designed to reduce chronic malnutrition among children less than three years of age living in poor rural areas in four regions of Peru (Lechtig *et al.*, 2009). The program implemented a package of health and nutrition interventions that included promotion of adequate maternal nutrition, exclusive breastfeeding for six months and continued breastfeeding for two years, adequate complementary feeding, early child stimulation, growth monitoring, vitamin A (children only) and iron (pregnant and lactating women and children) supplementation, iodized salt, micronutrient-rich food consumption, improved control of child illness, and personal and family hygiene. Cross-cutting all activities were participatory processes to encourage local management, capacity development and resource mobilization. Program implementers worked together with the local health sector, community leadership and nongovernmental organizations. In 2004, the program covered approximately 75,000 children U3 and 35,000 pregnant and lactating women living in 223 communities. Evaluation of program effectiveness was done using cross-sectional household surveys at baseline in 2000 and endline in 2004. Anaemia (Hb cut-off not reported) prevalence in children 0-35 mo at baseline was 76% overall (N=1,402) and varied from 55% to 88% across the four regions. At endline, the overall prevalence of anaemia was 52% ($p<0.01$ for comparison with baseline) and significant reductions were observed in all four regions. The authors noted that the highest impact (50% reduction in anaemia) was observed in the region where high coverage (>80%) for iron supplementation every other day was achieved. The prevalence of stunting also decreased from 54% to 37% ($p<0.01$). Vitamin A deficiency (serum retinol concentration <20 µg/L) was present in 30% of children at baseline and decreased to 5% in 2004 ($p<0.01$).

Conditional cash transfer programs in Latin America are another example of large-scale efforts to address both the underlying and immediate determinants of child undernutrition. Conditional cash transfer programs provide cash transfers to poor families with the condition that they comply with specific program requirements, such as use of maternal and child preventive health, nutrition and care services, school enrolment and attendance of school-age children, and, in some cases, provision of a micronutrient-fortified food or micronutrient supplements (Leroy *et al.*, 2009). Programs in Mexico, Nicaragua and Honduras have specifically targeted child anaemia and evaluated impact on this outcome.

In Mexico, PROGRESA/Opportunidades provided participating families with nutrition education, health care and cash transfers. Children and pregnant/lactating women received a fortified food supplement, including 10 mg iron per daily ration. Several studies have assessed the program's effect on child anaemia. A randomized effectiveness study in rural communities found that one year of intervention was associated with improved linear growth and lower rates of anaemia in children 6-12 mo, with larger effects seen in the youngest and poorest children benefiting from the program (Rivera *et al.*, 2004). Another study of child health outcomes in rural areas observed that children 12-48 mo in program areas were 25.5% less likely to be anaemic than those in areas not yet benefiting from the program (Gertler, 2004). A comparison of mean haemoglobin and anaemia prevalence in children 2-4 y in urban areas showed no effect of the program in children 3-4 y; however, beneficiary children 2-3 y had a 4 g/L higher mean haemoglobin compared to control children of the same age, although this did not translate into significantly different prevalence of anaemia (Leroy *et al.*, 2009). In a study designed to estimate what independent effect the cash transfer component may have had, results showed that larger cumulative cash transfers to the household were associated with significantly better child growth and development outcomes but not haemoglobin concentration (Fernald *et al.*, 2008).

Modeled after the PROGRESA program, Red de Protección Social also provided cash transfers to disadvantaged families in Nicaragua, with the condition that they attend educational workshops, bring children for regular preventive health care appointments

and ensure children attend school. Children U5 received growth monitoring, vitamin and iron supplements, anti-parasitic treatment and routine vaccinations. A randomized evaluation of impact of the package of interventions in the pilot phase found that while the program improved household diet, health-care services, child nutritional status and significantly increased the proportion of mothers receiving iron supplements for their children (56% increase in intervention areas compared to 20% increase in control areas), no change in anaemia among children 6-59 mo was evident, with approximately 33% of children anaemic at baseline in 2000 and follow-up in 2002 (Maluccio & Flores, 2004).

The IMCI strategy was adopted by the World Health Assembly in 1995 for reducing U5 morbidity and mortality and promoting child growth, development and survival. The strategy focuses on improving health worker skills, health systems and family and community practices which support child survival. An integrated package of interventions is promoted that includes prompt recognition and effective treatment of illnesses like diarrhoea and malaria, the prevention of illness through improved nutrition including breast-feeding, vaccination, and the promotion of ITNs, micronutrients such as vitamin A and iron, and deworming. Based on its design, IMCI is expected to contribute to the reduction of anaemia in young children. However, due to challenges experienced in achieving full scale implementation at health facility and community levels, this level of impact has not been fully evaluated. In Tanzania, where the Multi-Country Evaluation of IMCI measured household level indicators of child health, including anaemia, the comparison between two districts that implemented IMCI with two districts that did not, showed no evidence for an effect of IMCI, with similar improvements observed in anaemia and nutritional status of children 6-59 mo in all four districts (MCE, 2003).

Other examples of integrated anaemia control programs are available but have either not been evaluated for their impact on child anaemia or have not been published. One example of an unpublished program that has been successful in reducing child anaemia is Nicaragua's Integrated Anaemia Control Strategy, developed as part of a National Micronutrient Plan (Mora, 2007). The strategy includes iron/folic acid supplementation for pregnant women and children U5; periodic delivery of

anthelminthic medications to children 2-10 y; fortification of wheat flour with iron and B-vitamins; interventions to control vitamin A deficiency (supplementation and fortification of table sugar); behavioural change communications; comprehensive training of health service personnel, community health volunteers and non-governmental organizations; strengthening of other public health interventions; and a program monitoring and evaluation system. Although early assessments of the impact of fortification efforts showed no change in anaemia in young children (28.5% in 1993 and 33.5% in 2000), following a strengthening of the supplementation program, child anaemia decreased to 16.2% by 2003.

Interventions to address child anaemia are increasingly being tested and implemented in contexts where other concurrent efforts to address nutrition and health are well underway, often at a national scale. For example, recent evidence suggests that incorporating deworming into Uganda's national vitamin A supplementation program resulted in improved weight gain (Alderman *et al.*, 2006) and national ITN distribution efforts during child health weeks are reducing the malaria burden in young children (WHO, 2008). An evaluation of a large-scale program in Madagascar that delivered an integrated package of nutrition interventions within the Essential Nutrition Actions framework revealed significant improvements in exclusive breastfeeding rates, child feeding practices, deworming coverage of children 12-23 mo and iron-folic acid supplementation during pregnancy (Guyon *et al.*, 2009). These successes are expected to result in enhanced impact overall on the nutrition and health status of children, including reduced anaemia levels, but evaluations of anaemia as a specific outcome are likely distant.

In the meantime, there remains a need for documented evidence for effectiveness of integrated programs to address anaemia that are implemented in real-life conditions and for a longer period of time to allow for changes in behaviour, lifecycle determinants (e.g. nutrition in pregnancy influencing child iron status at birth) and food production/access.

## 2.7 Importance of context in understanding program outcomes

Another major gap in the literature is detailed documentation of complex public health and nutrition program interventions and the context in which they are delivered. Pawson and colleagues (2005) make the argument that public health services are "complex social interventions which act on complex social systems…not 'magic bullets' which will always hit their target, but programs whose effects are crucially dependent on context and implementation" (p. S1:21). In light of this reality, the public health program evaluation community has called for increased attention to and publication of program theory models, measures of the fidelity of program implementation and contextual factors that may be important to the observed outcomes (Armstrong *et al.*, 2008).

One important feature of complex public health and nutrition interventions is their underlying theoretical basis. Program theories or intervention logic models describe how the intervention is intended to bring about change in the intended outcomes (Armstrong *et al.*, 2008) and may be explicit or implicit (Pawson *et al.*, 2005). Program theory frameworks are useful in identifying the indicators to be evaluated in order to understand and document impact pathways, including inputs, outputs, outcomes and potential mediating and confounding factors (Olney *et al.*, 2009). Recent examples of careful description, measurement and analysis of nutrition program processes have demonstrated the value in understanding the pathways to successful outcomes (Robert *et al.*, 2006; Loechl *et al.*, 2009).

Once the program theory and design have been described, a second essential aspect of understanding outcomes of complex interventions is the degree to which the interventions were implemented as planned. This is often described as "integrity of intervention" (Armstrong *et al.*, 2008) or "aspects of fidelity" (Dane & Schneider, 1998). Program interventions often follow complex and dynamic pathways and the outcomes of an intervention are based on the cumulative effect of the various mechanisms, actors and systems at work (Pawson *et al.*, 2005; Bisset & Potvin, 2007). It

is important to avoid what Pawson and colleagues (2005) call “label naiveté”, the tendency to make assumptions about how an intervention was implemented based on its title which is related to a general or standard program theory. Modifications to program delivery may result in enhanced or attenuated outcome effects; documenting how the intervention was actually delivered provides valuable information that can contribute to this discussion. Although there is no current consensus on how intervention integrity is assessed, Dane & Schneider (1998) propose using five measures of fidelity of program delivery: adherence, exposure, quality of delivery, participant responsiveness and program differentiation. Armstrong et al. (2008) also recommend reporting intensity, duration and reach for the various intervention components.

Finally, the importance of context in understanding the outcomes of complex public health and nutrition interventions has been emphasized. The same intervention delivered in two different contexts may have completely different results. In fact, the effect of an intervention may be due, to varying degrees, to pre-existing aspects of the context (Jackson & Waters, 2005). When seeking to understand the outcomes of an intervention, it is essential to try and understand the social, economic and political context in which it was developed and implemented (Armstrong *et al.*, 2008). Studies may be contextualized in terms of organizational culture and leadership, resource allocation, staffing levels and capabilities, characteristics of the target population, competing local priorities or influences and other aspects of the system (Hawe *et al.*, 2004; Pawson *et al.*, 2005). The evolution of disease risk factors and secular trends in prevalence are also aspects of contextualization that have relevance for the interpretation of different outcomes (McLaren *et al.*, 2007).

## 2.8 Review of risk factors for anaemia in children 24-59 mo

Our understanding of the risk factors for anaemia in young children is informed in large part by the results of cross-sectional surveys showing the distribution of anaemia among children with different characteristics. Statistical modeling of multiple risk factors for anaemia enables researchers to account for the variation due to age, sex and socioeconomic status and identify those factors that independently increase the risk

of anaemia in a population group. This section provides an overview of the studies that have looked specifically at risk factors for anaemia among children 24-59 mo in sub-Saharan African countries.[6] A summary of these studies is presented in Table 2.4.

A recent evaluation of a national integrated child health campaign in Togo measured the change over time in anaemia among children U5 in two cross-sectional household surveys before (2004; n=2521) and after (2005; n=2813) the campaign (Terlouw *et al.*, 2010). Among children 18-59 mo in three districts, the prevalence of moderate to severe anaemia (Hb <80 g/L) ranged from 15-17% in 2004 to 9-16% in 2005. Malarial anaemia (parasitaemia + Hb <80 g/L) ranged from 10-14% in 2004 to 7-13% in 2005. A 50% reduction in moderate to severe anaemia was observed in the pooled sample of children U5, along with an increase of 6 g/L in mean haemoglobin level. In 2005, ITN users had higher mean haemoglobin than nonusers (1.7 g/L, 95% CI 0.3-3.1, adjusted for age and district).

The prevalence of anaemia was assessed among children U5 (n=2410) in southwestern Ethiopia as a baseline measure for a malaria control trial (Deribew *et al.*, 2010). About one third of children were anaemic (29% and 36% in intervention and control areas, respectively) but very few severely anaemic (<2% in both areas). The prevalence of malaria parasitaemia was also low (8-11%) and predominantly due to *P. vivax* infection; thus only 3-4% of children had malarial anaemia.

Cross-sectional household surveys conducted in six districts of Malawi in 2005 and 2008 assessed the change over time in anaemia and parasitaemia among children 6-30 mo as indicators of progress by the national malaria control program (Mathanga *et al.*, 2010). While overall anaemia (Hb <110 g/L) remained stable over time (78% and 77% in 2005 and 2008, respectively), the prevalence of moderate/severe anaemia (Hb <80 g/L) decreased from 18% in 2005 to 15% in 2008. Parasitaemia prevalence also decreased from 19% in 2005 to 17% in 2008. Although the analysis did not look at the risk relationship between anaemia and malaria, moderate/severe anaemia was associated

[6] The potential influence of the new WHO Child Growth Standards as the international reference must be noted. Most studies referenced here used the NCHS growth reference curves to calculate anthropometric z-scores. De Onis and colleagues (2006) compared the WHO standards and NCHS reference among children 0-59 mo from Bangladesh (DHS 1996-7) and found a decrease in underweight prevalence of ~6% and increase in stunting of ~10% when the WHO Growth Standards were used.

with history of fever, clinical malaria and not sleeping under a bednet or ITN in both years and with current fever only in 2008. The youngest children (6-8 mo) had higher anaemia levels in 2005 but not in 2008. Household wealth quintile was not associated with anaemia in 2005 but in 2008, children from the poorest quintiles had higher levels of anaemia than those in the wealthiest quintile. Results from data collected from children 6-30 mo attending routine EPI services at three health facilities were largely similar to those observed at the household level.

A national survey of children 0-60 mo (n=552) in Equatorial Guinea reported that 69% were anaemic (Hb <110 g/L) and 8% severely anaemic (Hb <80 g/L) (Custodio *et al.*, 2008). Stunting prevalence was moderate overall (35%), but higher among children 24-60 mo (46%). Malaria parasitaemia status, diarrhoea in the past 15 d and immunization status were not associated with moderate/severe anaemia (Hb <80 g/L) for the overall sample or for children from rural areas. In the overall model, high household socioeconomic level was protective (OR 0.29; 95% CI 0.09, 0.93) and mother's parity over 5 was associated with an increased risk of anaemia (OR 4.03; 95% CI 1.20, 13.47). Among children from rural areas, caregiver education level and a measure of community endowment were negatively associated, and child fever in the past 15 d and hunting by a member of the household were positively associated with anaemia (OR not reported for rural area model).

Individual, household and community level risk factors for anaemia among children 6-59 mo were analyzed using simple and multi-level regression methods on 2001 DHS data from Benin and Mali (Ngnie-Teta *et al.*, 2007). Anaemia levels were very high (82-83%) in both countries, with the majority moderately anaemic (52-53% with Hb 70-99 g/L); chronic undernutrition was also prevalent (52% and 71% stunting in Mali and Benin, respectively). Stunted children had a higher risk of moderate and severe anaemia, an association that remained significant in multivariate models (OR 1.8). Children with a recent diarrhoea episode were also at increased risk of anaemia in both countries (OR 1.46 in Mali; 2.34 in Benin). Not sleeping under a bed net (OR 1.75) and maternal education (OR 1.77) were additional risk factors for anaemia among children in Benin, but not Mali. Malian children from rural areas were twice as likely to

be anaemic than those from urban areas. Based on multi-level regression models, approximately 14-19% of the variability in the risk of anaemia was attributable to differences between communities.

A study in northern Ghana examined the relationships between anaemia, malaria infection and nutritional indices by season in children 6 mo to 9 y (Ehrhardt *et al.*, 2006). Two cross-sectional surveys were conducted, one in the rainy season (n=2119) and the other in the dry season (n=2109). Overall, anaemia was seen in 64% of children, and 26% were stunted. Parasitaemia prevalence varied by season, ranging from 49% in the dry season to 57% in the rainy season. Underweight and not stunting was associated with an increased risk of anaemia (OR 1.68; 95% CI 1.38, 2.04), similar to that of *P. falciparum* infection (OR 1.40; 1.14, 1.72). Rainy season and rural residence were also independent risk factors for anaemia in these children.

A cross-sectional survey of children 9 mo to 5 y (N=2532) carried out during the high malaria transmission season in Togo found very high levels of anaemia, with 84% of children with Hb <110 g/L, 22% with Hb <80 g/L and 0.5% with Hb <50 g/L (Eliades *et al.*, 2006). As expected, malaria parasitaemia was also very high (62%) and this risk factor increased the risk of moderate/severe anaemia (Hb <80 g/L) by an OR of 2.3 (95% CI 1.8, 3.5). Anaemia was not associated with economic quintiles in this sample.

In Ghana, a study compared characteristics of children 1-9 y (n=296) from two communities and observed markedly higher levels of anaemia (66% vs. 35%), stunting (21% vs. 7%) and malaria parasitaemia (38% vs. 13%) in one compared to the other (Ronald *et al.*, 2006). Helminth infection in both areas was negligible. In multivariate modeling of anaemia risk overall, younger child age (OR 0.79 per 1-y increase; 95% CI 0.71, 0.88), *P. falciparum* infection (OR 3.92; 2.04, 7.54), male sex (OR 2.16; 1.28, 3.66) and community of residence (OR 3.76; 2.16, 6.56) were independent risk factors. The population attributable risk of anaemia was 16.5% for malaria and 7.6% for malnutrition.

Table 2.4: Summary of cross-sectional studies of anaemia risk factors in children 24-59 mo, sub-Saharan Africa

| Description of study | Anaemia prevalence[1] | Nutrition risk factors | Health risk factors | Other risk factors |
|---|---|---|---|---|
| **Togo** – children U5 in three districts before (2004; N=2521) and after (2005; N=2813) national child health campaign (Terlouw *et al.*, 2010) | • 18-59 mo:<br>2004: 15-17% Hb<80<br>2005: 9-16% Hb<80 | • None assessed | • Malarial anaemia (18-59 mo)<br>2004=10-14%; 2005=7-13%<br>• ITN-users 19% lower prevalence of Hb<80 (2005) | • Children 6-23 mo had highest anaemia prevalence and lowest mean Hb in both surveys<br>• Northern district |
| **Ethiopia** – children U5 (n=2410) in intervention and control areas (Deribew *et al.*, 2010) | • 29 & 36% Hb<110<br>• 1.0 & 1.7% Hb<70 | • None assessed | • 11 & 8% malaria parasitaemia<br>• 32 & 25% fever<br>• 3 & 4% malarial anaemia | • Malaria prevalence not associated with age, sex or birth order |
| **Malawi** – children 6-30 mo across six districts in 2005 (N=926) and 2008 (N=4565) (Mathanga *et al.*, 2010) | • 2005: 18% Hb<80<br>75% Hb<110<br>• 2008: 15% Hb<80<br>77% Hb<110<br>• Mean Hb<br>2005: 101; 2008: 97 | • None assessed | • Malaria parasitaemia<br>2005: 19%; 2008: 17%<br>• History of fever<br>2005: 42%; 2008: 27%<br>• Slept under ITN<br>2005: 41%; 2008: 37%<br>• History of fever, clinical malaria, not sleeping under net/ITN associated with Hb<80 both years; current fever in 2008 | • Younger age group associated with Hb<80 in 2005 but not 2008<br>• Lower wealth quintile associated with Hb<80 in 2008 but not 2005 |

*Continued on next page*

Table 2.4: Summary of cross-sectional studies of anaemia risk factors in children 24-59, sub-Saharan Africa, *continued*

| Description of study | Anaemia prevalence[1] | Nutrition risk factors | Health risk factors | Other risk factors |
|---|---|---|---|---|
| **Equatorial Guinea –** national survey of children 0-60 mo (N=552) (Custodio *et al.*, 2008) | • 69% Hb<110<br>• 8% Hb<80 | • 35% stunted (46% for 24-60 mo)<br>• 11% underweight | • Morbidity prevalence not reported<br>• In rural subsample, diarrhoea associated with increased risk of Hb<80 (OR not reported) | • Anaemia highest in two youngest groups (78% 0-5 mo; 75% 6-11 mo), but age not independent risk factor of Hb<80.<br>• Overall sample: Hb<80 associated with socioeducational level (OR 0.29 for high level) & maternal parity (OR 4.03 >5 children)<br>• Rural model: Hb<80 negatively associated with caregiver education & community endowment; positively associated with hunting & recent fever (OR not reported) |
| **Mali** – national survey (DHS) of children 6-59 mo (n=2826) (Ngnie-Teta *et al.*, 2007) | • 83% anaemia<br>• 53% moderate<br>• 12% severe | • Stunted 42% (OR 1.8) | • Recent diarrhoea 23% (OR 1.46)<br>• Incomplete immunization 64%<br>• No bednet use 45% | • Risk 3-4x higher in <3y than 4-5y 19% of variability in risk of anaemia attributable to difference between communities; medium living standards lower risk of anaemia than high or low; rural area residence (OR 2.04) |

*Continued on next page*

Table 2.4: Summary of cross-sectional studies of anaemia risk factors in children 24-59, sub-Saharan Africa, *continued*

| Description of study | Anaemia prevalence[1] | Nutrition risk factors | Health risk factors | Other risk factors |
|---|---|---|---|---|
| **Benin** – national survey (DHS) of children 6-59 mo (n=2284) (Ngnie-Teta *et al.*, 2007) | • 82% anaemia<br>• 52% moderate<br>• 9% severe Hb<70 | • Stunted 34% (OR 1.81) | • Recent diarrhoea 16% (OR 2.34),<br>• Incomplete immunization 34% (OR 1.49),<br>• No bednet use 56% (OR 1.75) | • Risk 3-4x higher in <3 y than 4-5 y 14% of variability in risk of anaemia attributable to difference between communities; mother's education (OR 1.77); medium development community higher risk than low or high |
| **Northern Ghana –** children 6 mo-9 y; dry season (n=2109); rainy season (n=2119) (Ehrhardt *et al.*, 2006) | • 64% anaemia,<br>• 4% severe Hb<70<br>• Mean Hb in U5: 101 dry; 93 rainy | • U5 stunting 26%, underweight 29%, wasting 18%<br>• Underweight but not stunting independent risk factor for anaemia | • Parasitaemia varied by season (57% rainy, 49% dry in U5)<br>• *P.falciparum* infection & *P.malariae* coinfection independent risk factors for anaemia | • Age <5 y, rainy season & rural residence independent risk factors for anaemia |
| **Togo** – children 9 mo-5 y (n=2532) from 3 districts (Eliades *et al.*, 2006) | • 84% anaemic<br>• 22% Hb<80<br>• 0.5% Hb<50 | • No anthropometric or dietary data collected | • 62% parasitaemia (high transmission season); associated with risk of Hb<80 (OR 2.3; 95% CI 1.8, 3.5)<br>• 9% owned net | • Anaemia highest in children 6-23 mo (93-96%), still high in children 24-59 mo (76-88%)<br>• Hb not associated with economic quintiles. |

*Continued on next page*

Table 2.4: Summary of cross-sectional studies of anaemia risk factors in children 24-59, sub-Saharan Africa, *continued*

| Description of study | Anaemia prevalence[1] | Nutrition risk factors | Health risk factors | Other risk factors |
|---|---|---|---|---|
| **Ghana** – children 1-9 y (n=296) in 2 communities near Kumasi (Ronald *et al.*, 2006) | • M: mean Hb 113, 35% Hb<110, 2% Hb<80;<br>• MZ: mean 105, 66% Hb<110, 3% Hb<80 | • Stunting 7% (M) & 21% (MZ)<br>• Anaemia associated with stunting (47% nonstunted vs. 71% stunted, p<0.01), but not multivariate model | • Parasitaemia 13% (M) & 38% (MZ); independent risk factor (AOR 3.92)<br>• Univar: *p.falciparum* infection & clinical malaria | • Independent risk factors: younger age (AOR 0.79), MZ residence (AOR 3.76) and male sex (AOR 2.16)<br>• Univar: education, ethnic group, SES, chemical use, nearest health facility, male |
| **Kenya** – children <36mo (n=2774) in area benefiting from ITN intervention (Desai *et al.*, 2005) | • No ITN villages: 76.1% Hb<110 11% Hb<70 Mean Hb 98.7<br>• ITN villages: 71% Hb<110 8.3% Hb<70 Mean Hb 95.2 | • Overall stunting 25%<br>• No ITN model: stunted children lower Hb (−5.2; 95% CI −8.3, −2.1) & increased risk of malaria parasitaemia (OR 1.87 adj for age; 95% CI 1.25, 2.79) | • Malaria parasitaemia 57%<br>• Helminthiasis in children ≥30 mo was >40%;<br>• Risk factors for lower Hb: history of fever, pale body, body weakness, diarrhoea, soil-eating, current fever & malaria parasitaemia<br>• Odds of Hb<70 increased with increased parasite densities but also associated with low density infection (OR 3.11) | • No ITN villages only: Head education level, wealth, no. of children U5 & distance to nearest ITN compound associated with lower Hb; only no. of children U5 had independent association |

*Continued on next page*

Table 2.4: Summary of cross-sectional studies of anaemia risk factors in children 24-59, sub-Saharan Africa, *continued*

| Description of study | Anaemia prevalence[1] | Nutrition risk factors | Health risk factors | Other risk factors |
|---|---|---|---|---|
| **Kenya** – children 0-36 mo (N=1862) in ITN beneficiary villages (Friedman *et al.*, 2005b) | • 71% Hb<110<br>• 8.3% Hb<70<br>• 6.6% Hb<70 + parasitaemia | • 25% stunted, 6% wasted, 22% underweight<br>• Higher risk of severe malarial anaemia in stunted (OR 2.65) & wasted (OR 2.00) children;<br>• Hb<70 associated with lower mean HAZ (-0.29) and WHZ (-0.36) | • 52% malaria parasitaemia<br>• 7.6% hookworm, 19% Ascaris<br>• 54% history of diarrhoea requiring treatment | |
| **Kenya** – children <5 y (N=414) in 4 lowland & 2 highland villages (Akhwale *et al.*, 2004) | • Lowland: 34%<br>• Highland: 12% | • 39% BMI <15th percentile (total population); not disaggregated for children | • Malaria 26-31%<br>• Hookworm 3.9% | • Proximity to health facility not associated with anaemia;<br>• Boys at higher risk of anaemia than girls in lowland villages |
| **Ghana** – all ages; two surveys at end of low & high malaria transmission seasons in northern district (Koram *et al.*, 2003) | • Mean Hb levels differed by ~7.5 g/L between low & high season | | • Parasitaemia in children 2-5 y ~50% low, 75-80% high season;<br>• Parasitaemia strongly associated with Hb in children <2 y e.g. 6-24 mo: 15 g/L lower if malaria positive | • Significant seasonal effect on Hb for youngest age groups (<6 mo, 6-24 mo, 2-3 y, 3-4 y);<br>• Residence in town associated with lowest levels of anaemia & parasitaemia; no seasonal effect |

*Continued on next page*

Table 2.4: Summary of cross-sectional studies of anaemia risk factors in children 24-59, sub-Saharan Africa, *continued*

| Description of study | Anaemia prevalence[1] | Nutrition risk factors | Health risk factors | Other risk factors |
|---|---|---|---|---|
| **Tanzania** – children 0-59 mo (N=1979) in 4 districts for IMCI baseline (Schellenberg *et al.*, 2003) | • 87% Hb<110<br>• 39% Hb<80<br>• 3% Hb<50 | • Mean Hb and Hb<80 associated with HAZ & WAZ<br>• (prevalence of stunting and underweight not reported) | • Anaemia associated with distance to transfusion center and bednet use, but not time to health facility or compliance with vaccination.<br>• 53% sick in past 2 weeks and morbidity associated with Hb (43% for Hb≥110, 51% for Hb 80-109, 58% for Hb 50-79, 69% for Hb<50); RR=1.28 (95%CI 1.14,1.42) for Hb<8. | • Anaemia associated with age, with highest anaemia prevalence in children 6-11mo;<br>• SES (quintiles)[7] effect marginal (p=0.07) for mean Hb, but lowest quintile had higher prevalence of Hb<80 (45% vs. 37% highest SES); not associated with Hb<50;<br>• Mean Hb & Hb<50 but not Hb<80 associated with altitude <1000 m vs. >1000 m |
| **Ivory Coast** – volunteer children 2-5 y (N=312) in 3 rural & 1 urban area (Asobayire *et al.*, 2001) | • 50% Hb<100; | • 63% iron deficiency<br>• 39% IDA | • 62% malaria infection (8% with clinical parasite load)<br>• 46% elevated CRP (positive correlation with malaria density)<br>• Both CRP & malaria density were negatively correlated with Hb. | • Very low haemoglobinopathy prevalence (none with sickle cell disease; 9% sickle trait carriers in overall population sampled, including school-age children & adults) |

*Continued on next page*

[7] "Cross validation between the resulting SES score & ht-for-age, known to be strongly associated with SES, confirmed that the score was a better predictor of ht-for-age than any single component alone" (Schellenberg *et al.*, 2003, p. 584)

Table 2.4: Summary of cross-sectional studies of anaemia risk factors in children 24-59, sub-Saharan Africa, *continued*

| Description of study | Anaemia prevalence[1] | Nutrition risk factors | Health risk factors | Other risk factors |
|---|---|---|---|---|
| **Kenya** – children 2-36 mo (N=318) (Verhoef *et al.*, 2001) | • 69% Hb<110<br>• 7% Hb<80 | • 53% ID (SF<12ug/L)<br>• 46% IDA | • Malaria 18% (6% fever); associated with lower mean Hb (11.4 g/L, p=0.0001)<br>• Inflammation 38% (hi CRP)<br>• No hookworm, 0.4% schisto | • Children 12-23 mo had highest prevalence of anaemia, ID & IDA |
| **Zanzibar** – children 4-71 mo (n=490) on Pemba Island (Stoltzfus *et al.*, 2000) | • 80.4% Hb<100<br>• 15.5% Hb<70 | | • Malaria parasitaemia >75%; <30mo: lower Hb associated with malaria, recent fever, male sex but not hookworm ≥30mo: lower Hb associated with hookworm but not malaria | • Severe anaemia strongly concentrated in children <18 mo (40% <70 g/L) |
| **Ethiopia** – children 6-60 mo (n=2080) (Adish *et al.*, 1999) | • 42% anaemia (mean Ht 35.4 ± 4.8%) | • Family no food reserves (OR 1.31) | • Hookworm 0.4%<br>• Malaria 0%<br>• Unsafe drinking water (OR 1.36) | • Anaemia risk higher in older children (OR 1.71), mothers who were ill (OR 1.25) & income below poverty line (OR 1.49) |

*Continued on next page*

Table 2.4: Summary of cross-sectional studies of anaemia risk factors in children 24-59, sub-Saharan Africa, *continued*

| Description of study | Anaemia prevalence[1] | Nutrition risk factors | Health risk factors | Other risk factors |
|---|---|---|---|---|
| **Kenya** - children 6-76 mo (n=460)<br>[part of a case-control study of malaria – only controls analyzed here]<br>(Brooker *et al.*, 1999) | • 76% anaemia<br>• 2.6% Hb<50<br>• Mean Hb 95.9 | • 37% stunted,<br>27% underweight<br>6% wasted | • Anaemia not associated with hookworm infection (yes/no) but higher risk if egg count >200 epg (91 vs. 77%); also higher risk of severe anaemia (8.6 vs 2.1%; OR=5.0).<br>• Hb not associated with Ascaris or trichuris infection.<br>• Malaria infection associated with lower mean Hb (14 g/L) & higher anaemia (84 vs 72%) & severe anaemia (3.8 vs 2.0; OR=2.2) | • Anaemia highest among children 6-11mos; risk lower per age-group increase (OR=0.95);<br>• Girls lower risk than boys (OR 0.5). |
| **Tanzania -** children 6 mo to 5 y (n=261)<br>(Tatala *et al.*, 1998) | • 17% Hb≥110 (40% ID)<br>• 16% Hb 100-109 (73% ID),<br>• 52% Hb 70-99 (68% ID)<br>• 15% Hb<70 (90% ID) | • ID 68% overall, only risk factor associated with anaemia<br>• Stunted 57%<br>• Underweight 50% | • Risk factor prevalence: hookworm 3.8% (n=184); schistosomiasis 5.1% (n=178); malaria 34% (n=250)<br>• None associated with anaemia | |

*Continued on next page*

Table 2.4: Summary of cross-sectional studies of anaemia risk factors in children 24-59, sub-Saharan Africa, *continued*

| Description of study | Anaemia prevalence[1] | Nutrition risk factors | Health risk factors | Other risk factors |
|---|---|---|---|---|
| **Tanzania** - children 6-40 mo (n=338) living in Bagamoyo area (Premji *et al.*, 1995) | • 74% anaemia (Ht<33%)<br>• 2.5% severe anaemia (Ht<20%) | • Majority of children were iron deficient, followed by normochromic macrocytic anaemia. | • Anaemia associated with fever & parasitaemia but not helminth infection.<br>• Anaemia associated with increased risk (OR 5.8) of symptomatic malaria | • Anaemia associated with age. |

[1] Unless otherwise noted, Hb <110 g/L used as cut-off to define anaemia.

A community-based household survey of children 0-36 mo (n=2774) in Kenya revealed high levels of anaemia (76%) and stunting (25%) (Desai *et al.*, 2005). Morbidity levels were also high, with 57% of children with malaria parasitaemia and over 40% of children ≥30 mo with helminth infections. Univariate analysis showed significantly lower mean haemoglobin levels in children who were stunted, wasted or underweight. Stunting remained a significant risk factor for anaemia in a multivariate model adjusted for survey year and age, with a mean haemoglobin difference of −5.2 g/L (95% CI −8.3, −2.1) in households without an ITN (final overall model). Stunted children were also at greater risk of having malaria parasitaemia than non-stunted children. Malaria parasitaemia was associated with a mean haemoglobin difference of −1.14 g/L (−1.14 [*sic*], −0.87). Although the odds of moderate/severe anaemia increased with increasing malaria parasite density, even very low density parasitaemia was associated with a three times higher risk of moderate/severe anaemia (OR 3.11; 95% CI 1.12, 8.61). Family size, history of fever, pale body, general body weakness, diarrhoea, soil-eating and concurrent fever were also associated with mean haemoglobin levels.

A study designed to evaluate whether undernutrition was associated with increased malaria morbidity in Kenya used data collected through three cross-sectional surveys of children 0-36 mo (Friedman *et al.*, 2005b). Results showed that 71% of children were anaemic, 25% were stunted and 52% had malaria parasitaemia. In multivariate models, stunted children had a higher risk of severe malarial anaemia (OR 2.65) than non-stunted children; a similar finding was observed for wasted children (OR 2.00).

Researchers in Kenya assessed the prevalence of anaemia and malaria in four lowland and two highland villages, including children U5 (N=414) as well as other groups (Akhwale *et al.*, 2004). The prevalence among children U5 of anaemia and malaria parasitaemia was correlated with altitude, with anaemia ranging from 57% at 1440 m to 11% at 2040 m and malaria ranging from 20-50% in the lowland villages to under 5% in the highland villages. Given the low prevalence of malaria among children from highland areas and the difference in anaemia between the two areas (34% in lowland, 12% in highland), the authors suggest that about two-thirds of the anaemia

among children in lowland areas can be attributed to their higher burden of malaria. Anaemia was also more prevalent in boys than girls (40% vs. 28%, $p<0.05$), but only in lowland areas. In the population as a whole, age and malaria infection were associated with anaemia but low BMI (<15$^{th}$ percentile), hookworm infection and proximity to a health facility were not.

Another population study was conducted in northern Ghana, assessing nutrition and health indicators of individuals of all ages at the end of the low and high malaria transmission seasons (Koram *et al.*, 2003). Significant seasonal differences in haemoglobin levels and malaria parasitaemia were observed among children from the four youngest age groups (<6 mo, 6-24 mo, 2-3 y, 3-4 y). Accordingly, anaemia prevalence (Hb <80 g/L) was higher at the end of the high transmission season for young children (<6 mo, 23% vs. 6%; 6–24 mo, 40% vs. 18%; 2–3 y, 33% vs. 10%). Parasitaemia was also strongly associated with lower haemoglobin in children <2 y. Residence in town was associated with the lowest levels of parasitaemia and anaemia, as well as little seasonal variation.

A community-based study of 2417 households in four districts in Tanzania looked at the prevalence and risk factors for anaemia in children U5 as part of the baseline survey of the Multi-Country Evaluation of IMCI (Schellenberg *et al.*, 2003). Low HAZ, WHZ and WAZ scores were all associated with an increased risk of anaemia. The percent of children sick in the past two weeks (53% overall) was strongly associated in a linear manner with haemoglobin concentration groups, increasing from 43% among children with Hb ≥110 g/L to 69% for children with Hb <50 g/L. No effect on mean haemoglobin was observed for distance to a health facility or vaccination status. There was a marginal effect of SES (quintiles) on mean haemoglobin ($p=0.07$); significantly more moderately/severely anaemic children (Hb <80 g/L) came from the lowest than the highest quintile (45% vs. 37%, respectively). The authors noted a surprising lack of differences between anaemic and non-anaemic children, apart from the role of poverty, malnutrition and age, highlighting the difficulty in targeting anaemic children.

The prevalence of iron deficiency with and without anaemia was assessed among several population groups from one urban and three rural areas of Côte d'Ivoire (Asobayire *et al.*, 2001). Among children 2-5 y (n=312), 50% were anaemic (Hb <100 g/L) and the mean haemoglobin concentration was 99 ± 15 g/L. The prevalence of iron deficiency was 63%, determined on the basis of the multiple criteria model, and 39% had IDA. The prevalence of malaria infection was very high (62%) and positively correlated with inflammation (elevated C-reactive protein), observed in 46% of children 2-5 y. Both malaria and C-reactive protein levels were negatively correlated with haemoglobin concentration. The authors concluded considerable overlap exists between IDA and infection or inflammation, particularly in young children.

A community-based survey of children 2-36 mo (n=318) in Kenya also observed high levels of anaemia (69% Hb <110 g/L), iron deficiency (53% serum ferritin <12 µg/L) and iron deficiency anaemia (46%) (Verhoef *et al.*, 2001). Haemoglobin concentrations were not associated with sex but children 12-23 mo had the highest prevalence of anaemia, ID and IDA. Malaria played an important aetiological role in this context, associated with a lower mean haemoglobin of 11.4 g/L ($p<0.001$) across all age groups, despite a relatively low prevalence of parasitaemia (18%) and fever (6%). C-reactive protein levels were high in 38% of children, suggesting underlying inflammation. No hookworm infection and very low schistosomiasis infection (0.4%) was observed.

Baseline characteristics of a cross-sectional sample of children 4-71 mo (n=5490) participating in an iron supplementation trial on Pemba Island, Zanzibar, were analyzed (Stoltzfus *et al.*, 2000). Anaemia prevalence was 80% (Hb <100 g/L) overall and 16% had severe anaemia (Hb <70 g/L); severe anaemia was strongly concentrated in children <18 mo (40%). Over 75% of children had malaria parasitaemia but this was not strongly associated with recent fever. Analysis of risk factors was stratified by age group (<30 vs. ≥30 mo). Haemoglobin was associated with malaria but not hookworm infection among children <30 mo whereas haemoglobin in children ≥30 mo was associated with hookworm infection and not malaria. Male sex and recent fever also predicted lower haemoglobin in the younger age group.

An assessment of anaemia risk factors among Ethiopian children 6-60 mo (n=2080) living in urban/semi-urban areas found that the mean haematocrit was 35 ± 4.8% and 42% of children were classified as anaemic (haematocrit <34%) (Adish *et al.*, 1999). Among a subgroup of anaemic children 24-60 mo, 43% had serum ferritin levels <12 μ/L. Malaria and hookworm infections were negligible in this context. Although children with diarrhoea, fever and stunting were at higher risk for anaemia in univariate analysis, these associations were attenuated with the addition of other variables in the model. Independent risk factors for anaemia included children >24 mo (OR 1.71), unsafe drinking water (OR 1.36), family not having food reserves (OR 1.31), mother being ill (OR 1.25) and income below the poverty line (OR 1.49).

Data on the risk factors for anaemia among Kenyan children 6-76 mo (n=460) were obtained from randomly selected controls in a case-control study (Brooker *et al.*, 1999). Anaemia prevalence was 76% overall and decreased with age; mean haemoglobin was 95.9 g/L. Undernutrition was moderate, with 37% of children stunted, 27% underweight and 6% wasted. Parasitic infections were prevalent in these children, as 34% had malaria parasitaemia, 29% were infected with hookworm, 20% with ascaris and 15% with trichuris. Based on logistic regression analysis, the risk of anaemia was lower for each older age group (OR 0.96) and girls (OR 0.53); risk was higher in children with malaria (OR 2.25) and those with higher hookworm infection intensity (>200 epg; OR 5.06).

In a study on anaemia and dietary intake in a Tanzanian sample of 660 households, children 6-59 mo (n=261) were found to have the highest level of anaemia overall (84%), including 67% moderately to severely anaemic and 60% concurrently iron deficient (Tatala *et al.*, 1998). Despite the high prevalence of malaria (34%) and stunting (57%) in these children, only iron deficiency retained a statistically significant association with anaemia in this age group in multivariate analysis.

Finally, in another study from Tanzania among children 6-40 mo (n=338), 74% were anaemia (haematocrit <33%) but only 2.5% were severely anaemic (Ht<20%) (Premji *et al.*, 1995). Based on stepwise regression results, anaemia was associated with

malaria parasitaemia and fever. Anaemic children were 5.8 times more prone to symptomatic malaria than non-anaemic children.

In summary, the findings from these studies carried out among young children across countries in sub-Saharan Africa confirm that anaemia is a major public health problem and iron deficiency, undernutrition, malaria and other types of morbidity are key contributing risk factors in most contexts. While helminth infections play an important role in some areas, their prevalence and association with anaemia varies widely in preschool children. Studies that included a marker of inflammation confirmed this can also be an important factor in understanding the aetiology of anaemia, particularly for interpreting measures of iron status and estimating the prevalence of iron deficiency in these populations. The few studies that included measures of health behaviours, maternal characteristics and household socioeconomic status found that, in general, these factors have less explanatory power than more immediate causes of anaemia. All studies confirmed that the risk factors for anaemia in young children are complex, their relationships change with age and sometimes season, and successful efforts to reduce them are much needed.

# CHAPTER 3: DESCRIPTION OF THE MICAH PROGRAM

# 3 Description of the MICAH program

Following the World Bank's publication in 1994 on the cost-effectiveness of addressing micronutrient malnutrition, the MICAH program was designed to address vitamin A, iron and iodine deficiencies through a package of integrated health and nutrition interventions. The program's overall design was established by World Vision Canada in consultation with the Canadian International Development Agency and participating country program implementation stakeholders. MICAH was implemented by World Vision in partnership with government ministries and other organizations in five African countries. With the goal of improving the nutrition and health status of women and children, the program interventions in each country included nutrition education, breastfeeding promotion, dietary diversification, micronutrient supplementation and fortification, malaria and other parasitic disease control, water and sanitation promotion, community and health facility level training and local and national level advocacy efforts.

The data for this study come from MICAH program monitoring and evaluation efforts in Ghana, Malawi and Tanzania[8]. These three countries represent the western, eastern and southern regions of the African continent. Since child health and nutrition outcomes are often largely a function of the context in which they live, this chapter seeks to provide an overview of each country context and describe in some detail the characteristics of the specific areas where program activities were delivered. Following this, the program interventions expected to address anaemia will be summarized and estimates made of the level of reach achieved by each country program for these interventions. These estimates were obtained through a review of MICAH internal documents.

[8] The program was also implemented in Ethiopia and Senegal but the data available from these two countries on child anaemia differed in significant ways from the other three and therefore were not included in this study. The Ethiopia program did not assess child U5 anaemia levels and the Senegal program moved to a different intervention area between the first and second phase.

## 3.1 Description of the country context

Ghana, Malawi and Tanzania were all relatively stable politically during the period under study (2000-2004). In terms of relative development status, Ghana was rated higher on the Human Development Index in 1997 and 2004 than Tanzania and Malawi, classified as a medium human development country while the other two were classified as low human development countries during this period (United Nations Development Programme, 1999; United Nations Development Programme, 2006).

Table 3.1 presents a comparison of population indicators by country, based on census data closest to the period under study. Malawi had the smallest total population but highest population density, one of the highest in Africa. Population growth rate and proportion of the population under 15 years of age was more similar across the three countries. While just over half of the population in Ghana lived in rural areas during this period, this proportion was higher in Tanzania (77%) and Malawi (86%).

Table 3.1: Demographic characteristics of Ghana, Malawi and Tanzania

| **Indicator** | **GHANA** | **MALAWI** | **TANZANIA** |
|---|---|---|---|
| | **2000 census** | **1998 census** | **2002 census** |
| Population, millions | 18.9 | 9.9 | 34.4 |
| Population density, persons per $km^2$ | 79 | 105 | 38 |
| Population growth rate | 2.7% | 2.0% | 2.9% |
| Proportion <15 y, % | 41 | 44 | 44 |
| Proportion living in rural areas, % | 56 | 86 | 77 |

(National Statistical Office (Malawi), 2001; Ghana Statistical Service, 2002; National Bureau of Statistics (NBS), 2002)

### 3.1.1 Child health and nutrition status

In terms of country-level indicators of health and nutrition, under-five mortality rates were highest in Malawi and lowest in Ghana; these rates declined between 1997 and 2004 in Malawi and Tanzania but stayed constant in Ghana (see Figure 3.1). The causes of death in children U5 were similar across countries, with roughly one quarter of deaths due to neonatal causes and malaria, diarrhoea and pneumonia accounting for a

large majority of deaths (UNICEF, 2008). Malaria was estimated to cause 33%, 14% and 23% of under-five deaths in Ghana, Malawi and Tanzania, respectively.

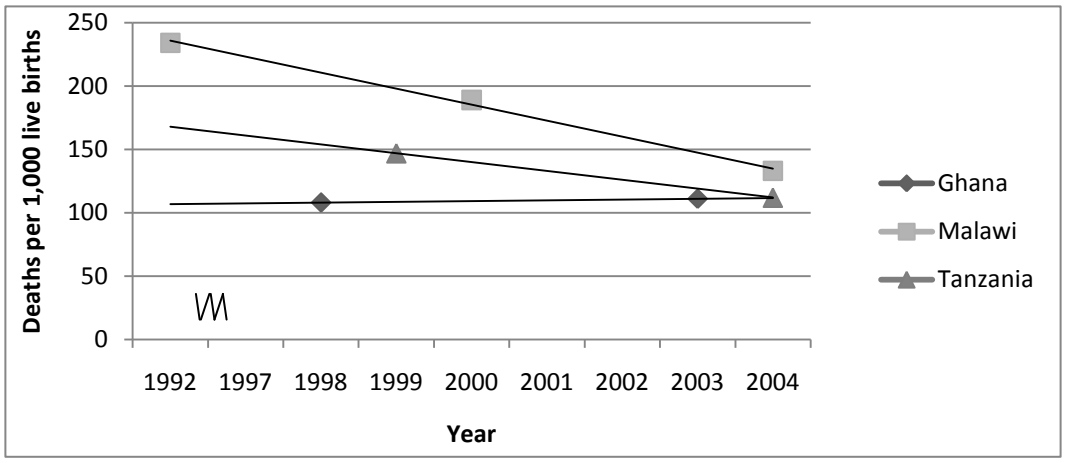



Figure 3.1: Comparison of under-five mortality rates over time by country
(Ghana Statistical Service (GSS) *et al.*, 2004; National Bureau of Statistics Tanzania & ORC Macro, 2005; National Statistical Office (Malawi) & ORC Macro, 2005)

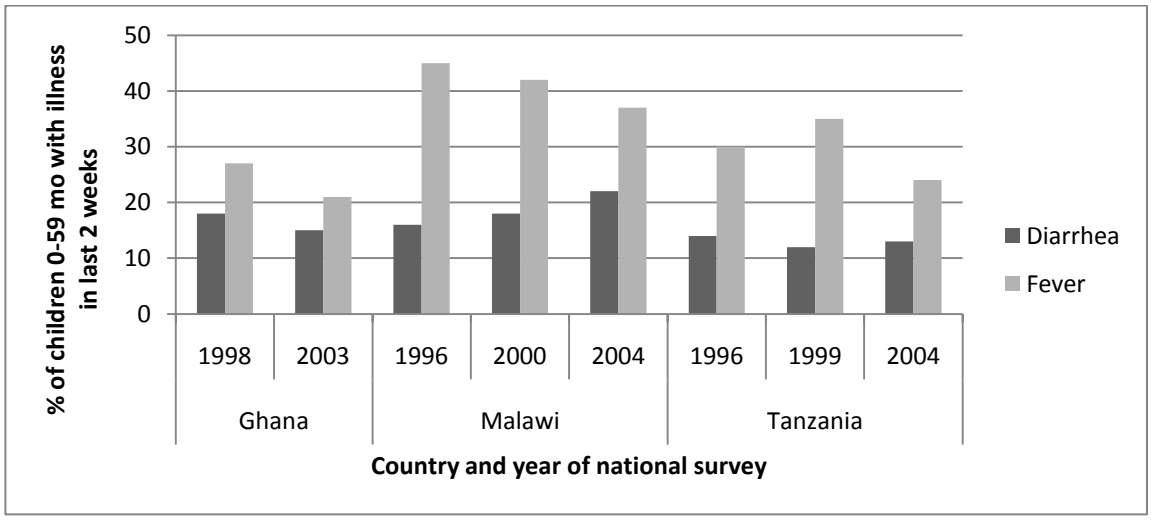



Figure 3.2: Comparison of child morbidity over time by country
(Ghana Statistical Service (GSS) *et al.*, 2004; National Bureau of Statistics Tanzania & ORC Macro, 2005; National Statistical Office (Malawi) & ORC Macro, 2005)

Child morbidity levels, measured as the prevalence of children 0-59 mo with fever and diarrhoea in the two weeks preceding the survey, remained relatively constant over the period under study in all three countries, as shown in Figure 3.2. Malaria was a major public health problem in all three countries, although levels of endemicity varied across the different geographical regions.

Although data on the prevalence among children U5 in these countries were not available, national HIV prevalence rates among adults 15-49 y ranged from 12% in Malawi (one of the highest in the world) to 7% in Tanzania and 2% in Ghana (Ghana Statistical Service (GSS) *et al.*, 2004; National Statistical Office (Malawi) & ORC Macro, 2005; Tanzania Commission for AIDS *et al.*, 2005). Among children, mother-to-child transmission (MTCT) accounted for about 25% of all new HIV infections in Malawi (National Statistical Office (Malawi) & ORC Macro, 2005). HIV/AIDS was estimated to cause 6%, 14% and 9% of under-five deaths in Ghana, Malawi and Tanzania, respectively (UNICEF, 2008).

All countries showed evidence of improvements in health service delivery over the period under study. In particular, national programs to deliver child survival interventions showed evidence of improved coverage between 1997 and 2004. Based on DHS surveys in each country in 2003-2004, vitamin A supplementation coverage among children 6-59 mo had increased to 46% in Tanzania and reached 65% and 78% of these children in Malawi and Ghana, respectively. The proportion of children using a bed net the previous night ranged from 15 to 31% across the three countries. The proportion of children 12-23 mo fully vaccinated was very similar across countries during this period, ranging from 64 to 71%.

Despite the improvement in health service delivery, the nutritional status of children in all three countries was relatively poor and showed little evidence of improvement. Figure 3.3 shows a comparison of the national prevalence of stunting, underweight and wasting among children 0-59 mo in the three countries as measured by DHS in 1999-2000 and 2003-2004. Stunting levels were slightly lower in Ghana (26%) compared to Malawi (49%) and Tanzania (44%) in 1999-2000. By 2003-2004, stunting decreased to 38% in Tanzania, remained constant at 48% in Malawi and increased to

30% in Ghana. Despite these differences, the age-related trend in the development of stunting was similar in all three countries (see Appendix A), with stunting prevalence reaching its highest point among children between the ages of 18-21 mo. Levels of underweight were very similar in all three countries, ranging from 25 to 29% in 1999-2000, and decreased slightly over time to 22%. Wasting levels were low in all contexts and over time.

National survey results showed a high prevalence of anaemia and micronutrient deficiencies among children U5 in all three countries. In Ghana, a survey by the National Nutrition Unit in 1994 found that 84% of preschool children were anaemic (Hb <110 g/L) (Ghana Health Service, 1995) and DHS results in 2003 found that 75% of children U5 were anaemic nationally (Ghana Statistical Service (GSS) *et al.*, 2004). Subclinical vitamin A deficiency was also a major public health problem in Ghana, as the 1997 national Vitamin A deficiency prevalence survey found that 76% of children 6-59 mo had moderate to severe vitamin A deficiency, based on serum retinol levels (Amoaful, 2001).

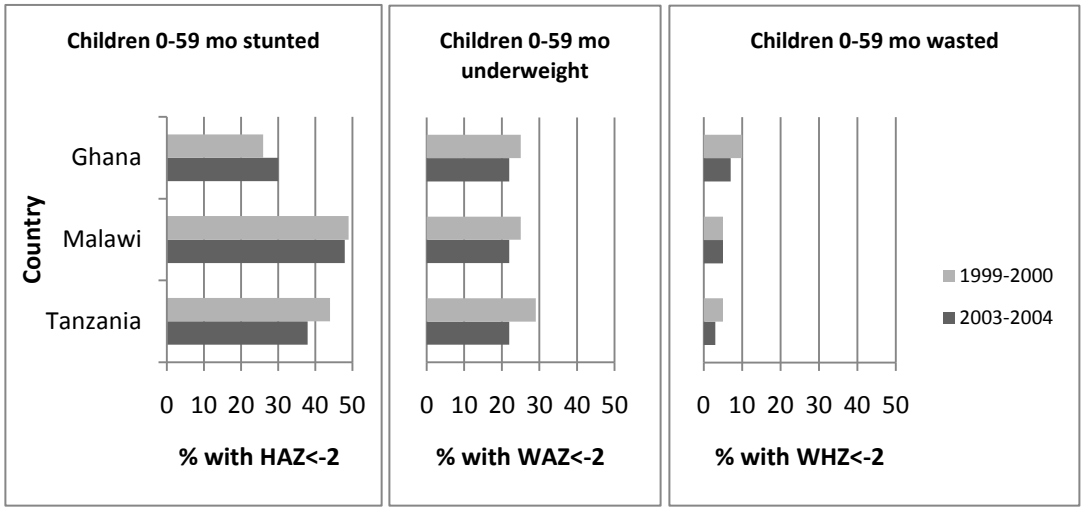



Figure 3.3: Prevalence of undernutrition indices by time period and country (based on DHS national data)

In Malawi, a National Micronutrient Survey conducted in 2001 (MOHP, 2003) found 60% of children U5 had sub-clinical vitamin A deficiency and 80% were anaemic. Among children under three years of age, 60% of anaemia was due to iron deficiency. The DHS 2004 results confirmed this, finding that 73% of children U5 were anaemic nationally. Suboptimal zinc status was also observed among Malawian children (Ferguson *et al.*, 1993). In Tanzania, iron deficiency is a serious problem among children (Stoltzfus *et al.*, 1997a; Tatala *et al.*, 2007). In 2004, when anaemia prevalence was assessed nationally, 66% of children U5 were anaemic (National Bureau of Statistics Tanzania & ORC Macro, 2005).

### 3.1.2 Dietary intake

A comparison of dietary intake in these three countries revealed some key differences and similarities. In general, the typical diet in Malawi and Tanzania is based on maize as the staple food, which is often prepared as a thick porridge for adults and children over the age of two years (Kibona *et al.*, 1995). In Ghana (specifically in the project area), the diet typically depends on a more diverse group of staple foods, including cassava and other tubers, plantain and maize. Across all three countries, fish is the main source of animal protein and meat is rarely consumed by rural households (Gibson & Hotz, 2001; Plahar *et al.*, 2002; Njelekela *et al.*, 2003). Groundnuts and legumes are important sources of protein and other nutrients in these contexts. Although staple foods are often supplemented with fruits and vegetables, the overall dietary diversity is considered low, especially in Malawi and Tanzania (Njelekela *et al.*, 2003; Lin *et al.*, 2007).

Data on the usual dietary intake among children 24-59 mo in these countries are limited but recent Demographic and Health Surveys have collected data on child feeding practices, including the age group 24-36 mo. From birth, most children are breastfed in all three countries, but less than half of infants 0-5 mo were exclusively breastfed during the period under study, a proportion that increased in all three countries from a range of 32-45% in 1998-2000 to 41-53% in 2003-2004. By the age of 24-36 mo, at least three quarters of children had been weaned in all three countries.

Figure 3.4 shows a comparison of results by country from DHS surveys in 2003-2004 for the proportion of non-breastfeeding children 24-35 mo consuming specific food groups in the previous 24 hours. While the vast majority consumed grains, the proportion consuming roots or tubers was highest in Ghana (50%) and lowest in Tanzania (25%), with 42% in Malawi. Approximately one third of children in all countries received legumes. Consumption of vitamin A-rich fruits and vegetables was also very common in all three countries. Estimates of consumption of meat, fish, poultry or eggs ranged from 35% in Tanzania to 52% in Malawi and 72% in Ghana. The higher proportions in both Ghana and Malawi may be due to the frequent consumption of fresh or dried fish in these countries (Plahar *et al.*, 2002; Yeudall *et al.*, 2005).

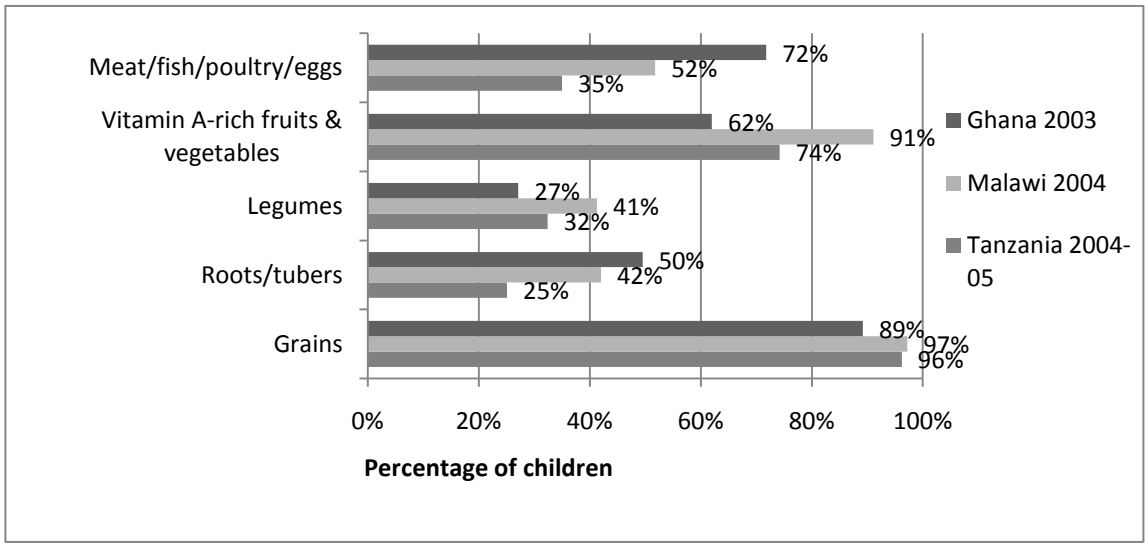



Figure 3.4: Comparison of food group intake in the 24 hours preceding the interview among non-breastfeeding children 24-35 mo by country
(Ghana Statistical Service (GSS) *et al.*, 2004; National Bureau of Statistics Tanzania & ORC Macro, 2005; National Statistical Office (Malawi) & ORC Macro, 2005)

Beyond food group consumption, it is also of interest to characterize and compare the adequacy of specific nutrients among children 24-59 mo in these countries. In a study of children 42-80 mo in southern Ghana and southern Malawi, Ferguson et al. (1993) found that most children had adjusted energy intakes below FAO/WHO

recommendations but adequate adjusted protein intakes[9]. Another study assessing the nutrient adequacy of Malawian children's diets found that inadequate intakes of multiple nutrients were common, with the most common deficits being iron, zinc, calcium and vitamins A and B-12 (Gibson *et al.*, 2003). Although fresh or dried fish were frequently consumed, especially by those living near Lake Malawi, and provided a good source of calcium, zinc and some haem iron, the consumption of meat and poultry was very low. Infrequent feeding is a concern in these countries as well, as most children are fed only 2 or 3 times a day (Kibona *et al.*, 1995; National Bureau of Statistics Tanzania & ORC Macro, 2005).

Several of these studies also have provided estimates of the average daily iron intake among children 24-59 mo, the nutrient of greatest interest in the analysis of anaemia. In the study by Ferguson et al. (1993) mentioned above, mean iron intake was 11.6 ± 2.4 mg and 13.1 ± 2.8 mg per day for children from Ghana and Malawi, respectively. Although bioavailability for iron and zinc was expected to be low in both groups of children due to the low level of animal protein consumed, the study estimated the bioavailability for zinc as 10% for Malawi and 20% for Ghana, due to the differences in phytate:zinc ratio of children's diets in these two countries (Ferguson *et al.*, 1993). Although not specifically estimated in this study, the bioavailability for iron is likely even lower than for zinc, given the high levels of phytate in the diet and negligible quantities of meat, fish or ascorbic acid-rich foods (FAO/WHO, 1988; Gibson, 2005). Another Malawian study of children 30-90 mo estimated the median daily iron intake as 9.6 mg (first, third quartile: 6.5, 12.2), with animal protein only contributing about 2% (Yeudall *et al.*, 2005).

Work by Tatala and colleagues (1998; 2007) in Tanzania showed that plant-based foods, such as cereals and vegetables, also accounted for the majority (85%) of iron intake in school-age (7-12 y) children. With a mean intake of 25 ± 11 mg/d, the authors estimated that half of the children had an iron intake below the RDI by

[9] Due to the high dietary fibre (non-starch polysaccharide) intakes of the children, energy and protein intakes were adjusted for digestibility. Protein intakes for further adjusted for the amino acid score of the mixed diet. The adjustment factors of 0.95 for energy and 0.68-0.85 for protein (based on study area) were applied to the dietary intakes.

FAO/WHO of 23 mg/d for children on a diet with low (5%) iron bioavailability[10]. Although a high intake of vitamin C was reported in the same study, primarily from consumption of locally growing fruits which were in season, the foods containing vitamin C tended to be taken outside the main meal times, thus not providing the expected effect of enhancing iron absorption (Hallberg et al., 1986).

### 3.1.3 National anaemia control policy and programs

In the late 1990's, national anaemia control policies and programs were primarily focused on pregnant women in most developing countries, particularly in terms of iron supplementation for anaemia control. However, between 2000 and 2004, all three countries were engaged in the development of national policies and programs expected to improve child survival, health and nutrition. Tanzania started nationwide scale-up of insecticide-treated nets in 1999 and of IMCI in 2000, and changed its drug policy for malaria in 2001 (Masanja *et al.*, 2008). The Tanzania National Food Fortification Alliance was established in 2003 to coordinate food fortification initiatives in the country. In Ghana, the development and launch of a national anaemia control strategy in 2003 provided a unifying framework for efforts by various partners and served as a guide for program design and prioritization of funding. The Roll Back Malaria initiative provided resources to support national efforts to roll-out IPT during pregnancy, distribute ITNs to pregnant women and young children and implement the new malaria treatment protocol. In Malawi, an office for the coordination of micronutrient issues was established in 1997 and played a key role in establishing several Task Forces for micronutrient deficiencies and contributing to the development of several national nutrition policies, including the National Plan of Action for the Prevention and Control of Micronutrient Malnutrition (2003 – 2008) and the Plan of Action for the Prevention and Control of Anaemia. A National Fortification Alliance was established in Malawi and developed a comprehensive strategy for centrally processed maize flour and sugar fortification; the first proposal to GAIN was submitted in 2005.

[10] Based on *in vitro* iron solubility analysis of these foods, only 1.2% of the iron in maize porridge and 5% of the iron in composite diets of maize gruel and legumes (e.g. maize+amaranth in a 80:20 ratio, 23 mg iron/100 g dry matter) was available for absorption (Tatala *et al.*, 2007).

In spite of these important steps forward in policy development and strategic planning that were expected to contribute to a reduction in anaemia levels among young children, the implementation of these strategies occurred slowly and likely were limited in the degree to which they influenced health outcomes of children at the community level between 2000 and 2004.

## 3.2 Description of the program area context

The following sections describe the characteristics of the areas in each country where the MICAH program was implemented, with a focus on the time period from 1996 to 2004. The information was gathered from various sources, including each country's original proposal (design), baseline (1996/97), follow-up (2000) and final (2004) survey reports, phase 1 and 2 progress reports, and personal communication from MICAH program managers in each country and at World Vision Canada.

### 3.2.1 Program design and organization structure

In response to growing evidence for the efficacy and cost-effectiveness of addressing micronutrient malnutrition in the mid-1990's, World Vision Canada worked with partners in Ghana, Malawi and Tanzania to design a community-based program with the goal of improving the nutritional and health status of women and children through cost-effective and sustainable interventions. In all three countries, World Vision worked in collaboration with government ministries, local community-based organizations and other non-government organizations. World Vision was the primary implementer in Ghana and Tanzania and acted as implementer and funder in Malawi. Funding was provided by the Canadian International Development Agency and World Vision Canada.

An overview of the program timeline and key events in each country is presented in Figure 3.5. The program planning was initiated earlier in Malawi in 1995 and required over two years for planning, proposal development and start-up, given the multiple partners involved in implementing the projects throughout the country. Proposal development took place in early 1997 in Ghana and Tanzania. Following the approval of each program proposal, countries conducted baseline surveys in

collaboration with research institutions to assess levels of micronutrient deficiencies in the program areas selected. Based on these results and discussions with stakeholders, the program's interventions were finalized and implementation began. Despite the different planning process in each context, implementation of program interventions at the community level started in early 1998 in all three countries. Initially funded for only two years, the program's first phase was extended several times, ending in 2002. It was then funded for a second phase from 2003 to 2005.

In terms of organizational structure, World Vision was the "host organization", so to speak, for the MICAH program in all three countries and as such, provided the baseline level of program quality in all three countries. In Malawi, where other organizations were directly involved in implementing MICAH, disparities in capacity for various functions (assessment, monitoring, reporting) were documented. The MICAH program worked in collaboration with World Vision's area development programs (ADPs) in all three countries. Although this was expected to be a highly complementary relationship, achieving an optimal level of integration proved to be difficult. Yet some evidence for enhanced MICAH implementation due to ADP program, staff and activities was observed in each context.

Government line ministries, especially the Ministry of Health (MOH) and Ministry of Agriculture (MOA), were important partners in all three programs. However, the degree to which various interventions were delivered through these systems varied. In Ghana and Tanzania, the majority of interventions were delivered by government health, agricultural and education staff, supported by program-trained community volunteers. Tanzania also focused intentionally on training of traditional healers from the informal health sector to improve health care provision. In Malawi, government partners were directly responsible for implementing the interventions in some project areas while in other project areas, interventions were delivered by NGO or other organizations as part of their own activities.

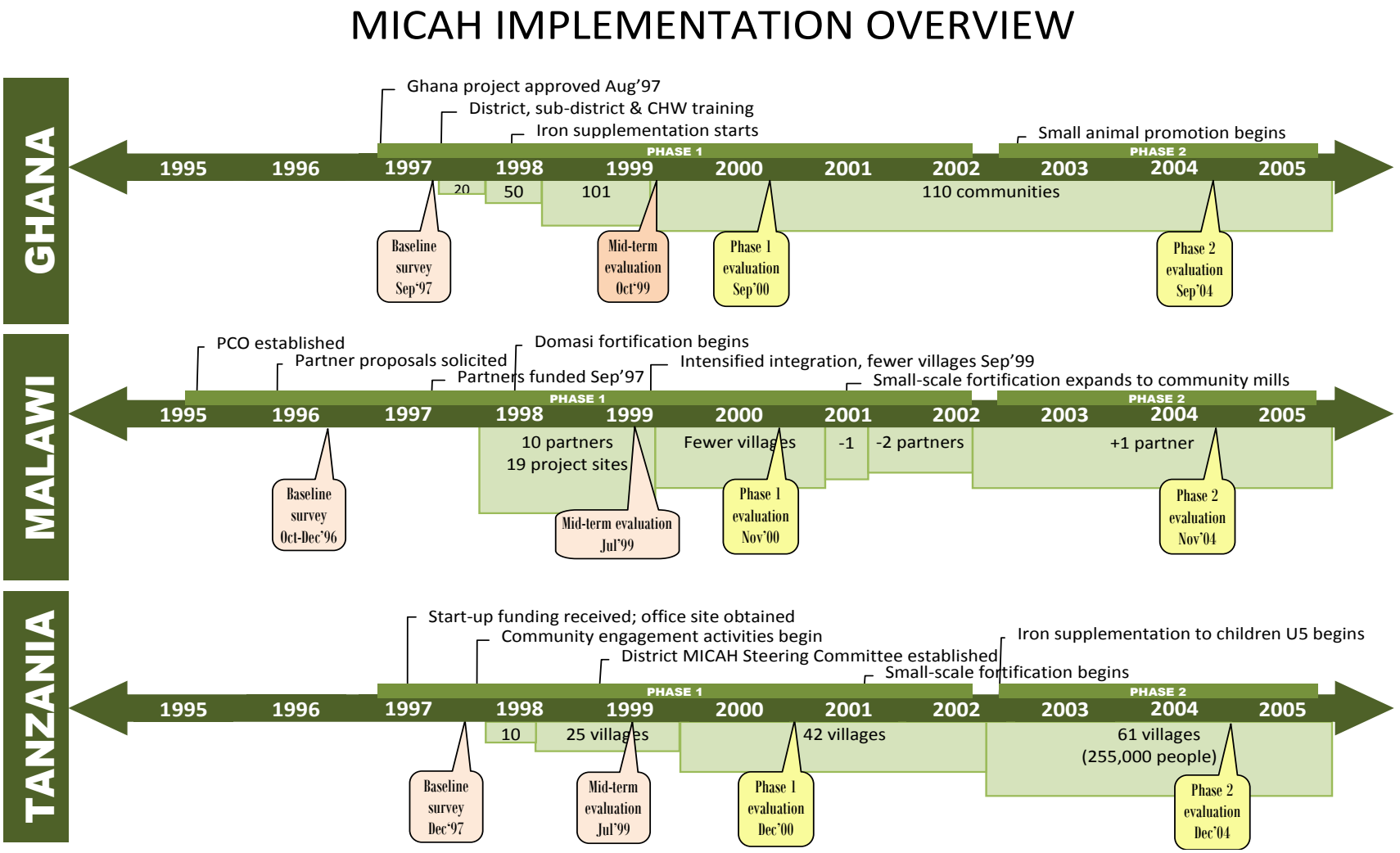



Figure 3.5: MICAH program timeline by country

Since most interventions were delivered at the community level, the programs also engaged directly with community leaders and local organizations. All programs invested heavily in training community volunteers in basic health, nutrition and hygiene. These volunteers played an important role in social mobilization, reinforcing program educational messages within their respective communities and monitoring community participation in specific activities. Each country program also established various community committees to take leadership for different sectors, including water and sanitation, malaria control and revolving drug funds[11] (Malawi only).

### 3.2.2 Program area characteristics and target groups

The MICAH program was implemented in specific districts of each country, based on a variety of criteria. Program interventions across all three countries were implemented in predominantly rural areas where families were dependent on subsistence agriculture, livestock keeping and, in some areas, fishing. However, differences across rural vs. semi-rural, ethnic and occupational groups were also observed.

#### 3.2.2.1 GHANA

In Ghana, the MICAH program was implemented in Kwahu South district in the Eastern Region (see Figure 3.6), an area selected by World Vision Ghana because the organization was already operational in the area and the district was known to have high goitre rates, indicative of iodine deficiency, one of the other micronutrients targeted by the program. Kwahu South District encompassed approximately 750 towns and villages in 1997 and was divided into eight sub-districts. The district's landscape was characterized by tropical forests, wooden savannah and savannah grasslands, as well as the Kwahu escarpment (up to 784 metres above sea level). Larger communities were highly accessible, served by a network of roads, but smaller villages in the valley area were linked by feeder roads that were often impassable during the rainy season. The rainy season extends from late March to early November with a short break in August and the dry season extends from December to March.

[11] Revolving drug funds are a means of improving access at the community level to basic medicines. After an initial capital investment by the program, drug supplies are replenished with monies collected from the sales of drugs.

Although the Ghana program's activities were delivered in collaboration with district government teams and therefore expected to benefit most of the district's population, women and children in specific program-targeted communities were expected to benefit most directly. Program communities were chosen by the District Health Management Team, with consideration being given to those that were under-serviced and inaccessible to health staff as well as those with a high prevalence of anaemia and goitre. The program targeted 50 communities in the first year and then expanded to an additional 60 communities in the second year, reaching an estimated population of 150,000 in these 110 communities in phase 1 and 2. Based on the estimated total number of children U5 in these communities (27,000 children, 18% of total population), the program aimed to reach 60% of eligible children, increasing from an initial target of 10,800 children U5 in 1998 to 16,200 in 2003.


Figure 3.6: Map of MICAH Ghana program area

### 3.2.2.2 MALAWI

In Malawi, the MICAH program was implemented in 14 of the 26 districts in the country, located across all three regions of Malawi. Program areas were selected from proposals developed by different agencies, including the Ministry of Health & Population (MOH) and the Ministry of Agriculture & Irrigation (MOA), as well as NGOs and mission hospitals, based on agency experience with nutrition, soundness of proposal and capacity to meet World Vision's financial and monitoring requirements. Table 3.2 provides a summary of the partners, the districts they targeted, their estimated beneficiary population and other characteristics.

Figure 3.7 shows a map of the program areas across the country. Given their broad geographic spread, it is difficult to briefly summarize the landscape and climate. Although the country is landlocked, Lake Malawi runs along much of its eastern boundary. The landscape is varied, with the Rift Valley that runs through the length of the country as well as fertile plains and mountain ranges with peaks ranging from 1,700 to 3,000 metres above sea level.

Malawi's climate is tropical, with rainfall and temperature varying based on altitude and proximity to the lake. In general, the weather is cool and dry from May to August, hot from September to November and the rainy season extends from November to April.

Although the country is largely self-sufficient for food, disruptions in the environment (drought or floods) and the market economy contributed to periods of widespread food insecurity during the program period. Serious food shortages were experienced in Malawi in 2001/02 and 2004/05. Regional differences in level of vulnerability have been documented. The population in the highland areas of the Northern Region tends to be largely food self-sufficient due to lower population density and more favourable soil conditions. The Southern Region is more densely populated and includes the country's largest commercial sector, providing opportunities for casual employment and higher prices for surplus food crops. The Central Region also has a major urban centre and major maize and tobacco production, but the area has been prone to drought and increasing population pressure on the land. One in four households in

this region produce only half of their grain requirement annually (Malawi National Vulnerability Assessment Committee, 2005). The Malawi National Vulnerability Assessment Committee estimated that one third of the population was perpetually in food production deficit (2005).

Although the program was designed as a multi-sectoral approach to addressing malnutrition, integrating health, nutrition, agricultural and educational activities, in the first year of implementation partners focused on those interventions which were most closely related to their area of emphasis or only one or two strategies with little accompanying education effort. In 1999, a Midterm Evaluation recommendation encouraged partners to scale back their original coverage targets in order to ensure that multiple interventions of a sufficient intensity would be implemented in villages and result in impact (i.e. depth rather than breadth). This shift in implementation was made shortly thereafter and resulted in a re-allocation of resources as well as a re-defining of MICAH intervention areas.

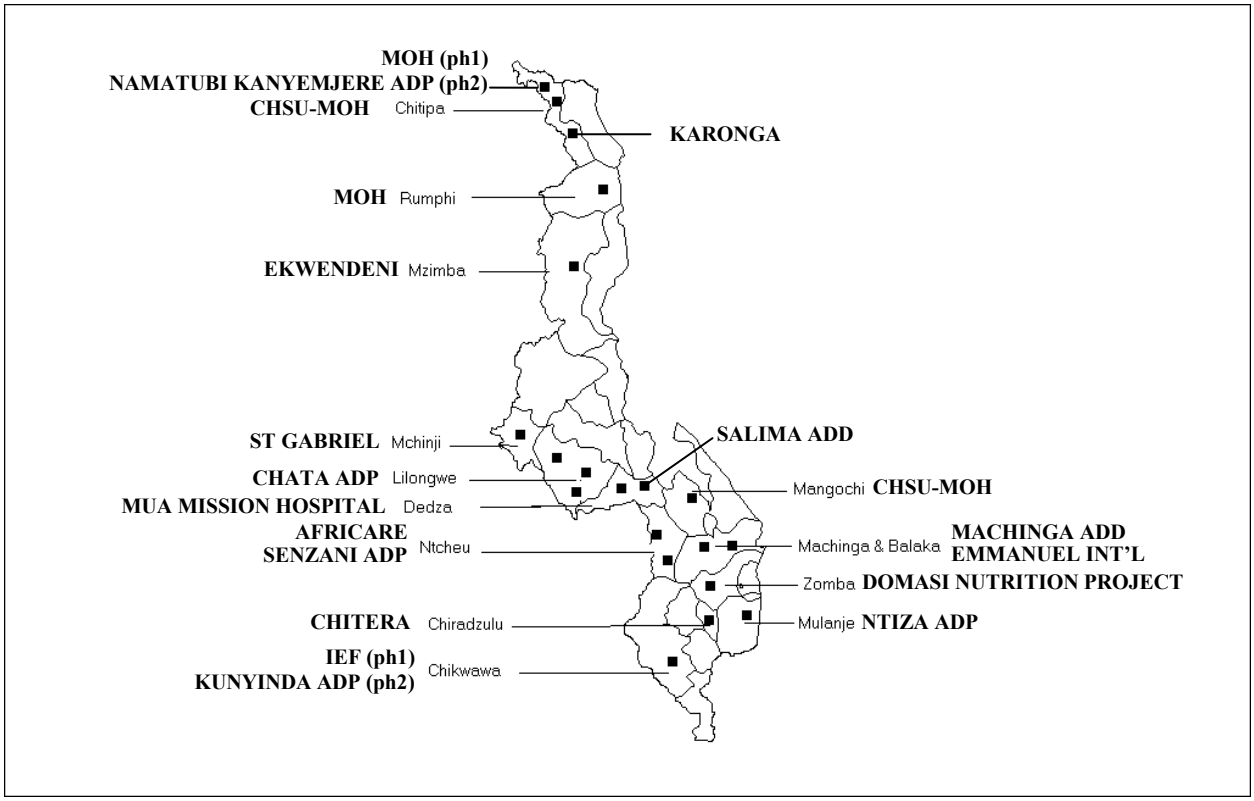



Figure 3.7: Map of MICAH Malawi program areas

The Malawi program's primary target groups were women of reproductive age, preschool and school-age children, and adolescent girls. In phase 1, the program was implemented in 19 sites with a combined population of approximately 1.8 million, including 305,471 households and 311,580 children U5. In phase 2, the program was implemented in 16 sites with an estimated 250,000 households and 210,000 children U5, but activities were directly targeted to 45,399 households (population est. 272,391). The program targets for activities reaching children U5 were 76,800 in phase 1 (25% of eligible) and 46,305 in phase 2 (22% of eligible). However, indirectly, the program benefit extended beyond intervention areas due to the concurrent work of MICAH partners in non-MICAH areas (e.g. MOH, MOA, ADPs) and the influence of MICAH on national-level policies and programs.

Table 3.2: MICAH Malawi implementing and technical support partners

| Implementing Partner | District | Beneficiaries | Characteristics |
|---|---|---|---|
| **NORTHERN REGION** | | | |
| Community Health Sciences Unit-Schisto-Chitipa | Chitipa | 26,000 | Parasitic disease control focus |
| Ekwendeni Hospital | N.E. Mzimba | 32,000 | MICAH complemented community health programs; operational research (iron supplements, malaria control); fortification |
| Karonga ADD (MOA) | Karonga | 14,000 | |
| Chitipa District Hospital IDD (ph 1)<br>Namatubi Kanyenjere ADP (WVM, ph 2) | Chitipa | 20,000 | |
| Rumphi District Office (MOH) | Rumphi | 28,800 | MICAH complemented hospital primary health care activities |
| **CENTRAL REGION** | | | |
| Africare | Ntcheu | 23,670 | Former Child Survival project; fish farming |
| Chata ADP (WVM) | Lilongwe | 25,000 | |
| Kabudula ADP (WVM) | Lilongwe | 20,627 | Former Child Survival Project |
| Mua Mission Hospital (ph 1 only) | Dedza | 25,000 | MICAH integrated with Safe Motherhood Programme |
| Salima ADD (MOA) | Salima | 4,500 | |
| Senzani ADP (WVM) | Balaka | 15,166 | |
| St Gabriel's Hospital | Lilongwe | 49,123 | MICAH complemented primary health care program; soya seed project; fortification |
| **SOUTHERN REGION** | | | |
| Chitera ADP (WVM) | Chiradzulu | 23,167 | |
| CHSU-Schisto-Mangochi | Mangochi | 26,000 | |
| Domasi Mission Hospital | Zomba | 5,852 | Commercial fortification unit |
| Emmanuel International | Balaka | 12,345 | MICAH complemented ongoing food security programs |

*...continued on next page*

Table 3.2: MICAH Malawi implementing and technical support partners, *continued*

| **Implementing Partner** | **District** | **Beneficiaries** | **Characteristics** |
|---|---|---|---|
| International Eye Foundation *(ph 1)* Kunyinda ADP *(ph 2)* | Chikwawa | 24,000 | Former refugee settlement area |
| Machinga ADD (MOA) | Machinga | 10,605 | |
| Ntiza ADP (WVM) | Mulanje | 10,178 | |
| | **TOTAL** | **396,033** | |
| **TECHNICAL SUPPORT PARTNER** | **LOCATION** | **ROLE** | |
| Programme Coordinating Office (WVM) | Lilongwe | Overall coordination | |
| Ministry of Health | Lilongwe | National Micronutrient Coordinator | |
| Ministry of Agriculture HQ | Lilongwe | Agricultural technical support | |
| CHSU-Lab | Lilongwe | Assessment (UI, serum retinol, salt titration) | |

### 3.2.2.3 TANZANIA

In Tanzania, WV Tanzania chose its Northern Zone of operations for implementing the MICAH program, targeting four divisions across two districts[12] in Tanga region, located in the northeast corner of the country (see Figure 3.8). This region was ranked in the fourth quintile of poverty-welfare in the country in 1999, based on the Poverty and Welfare Monitoring Indicators government report (United Republic of Tanzania, 1999). The climate in Tanga region is characterized by a long dry period from May to October, followed by bimodal rainy seasons, with short rains from October to December and the main rainy season from March to May. The topography ranges from semi-arid plains to mountainous areas. The climate and soils of the region enable production of a wide variety of crops.

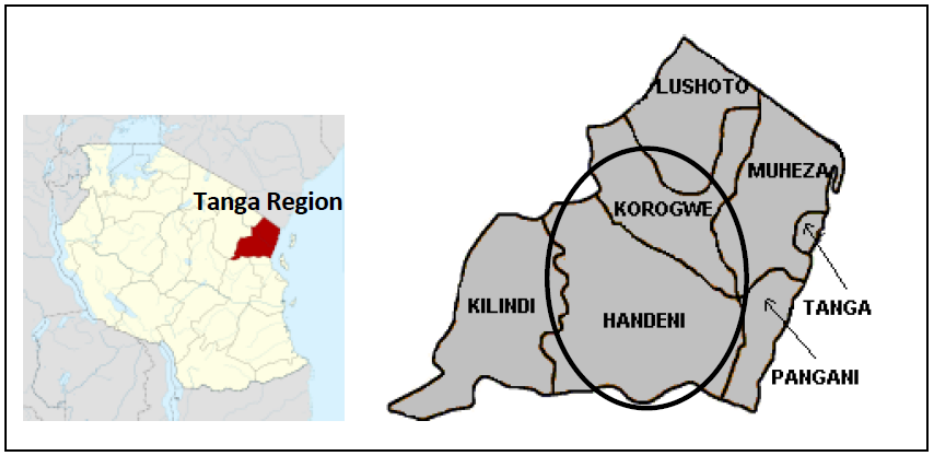



Figure 3.8: Map of Tanzania program areas

The MICAH Tanzania program originally targeted 25 villages with a population of 197,767 and estimated 39,600 children U5. In the second phase, 61 villages were targeted with an estimated total population of 255,420 (42,570 households). An estimated 51,000 children U5 were living in these areas and the program specifically targeted to reach 80% with vitamin A supplements and 50% with iron supplements. School children and women (both pregnant and non-pregnant) were other key target groups for program activities.

[12] The MICAH program in Tanzania was implemented in three divisions (Mazingara, Mzundu and Sindeni) in Handeni district and Mombo division in Korogwe district.

## 3.3 Program approach to anaemia

The MICAH programs in Ghana, Malawi and Tanzania were remarkably similar in terms of their efforts to address anaemia and engage with targeted communities. A summary of the program logic model for reducing anaemia prevalence is presented in Figure 3.9, below. The program's complete logical framework is presented in Appendix B.

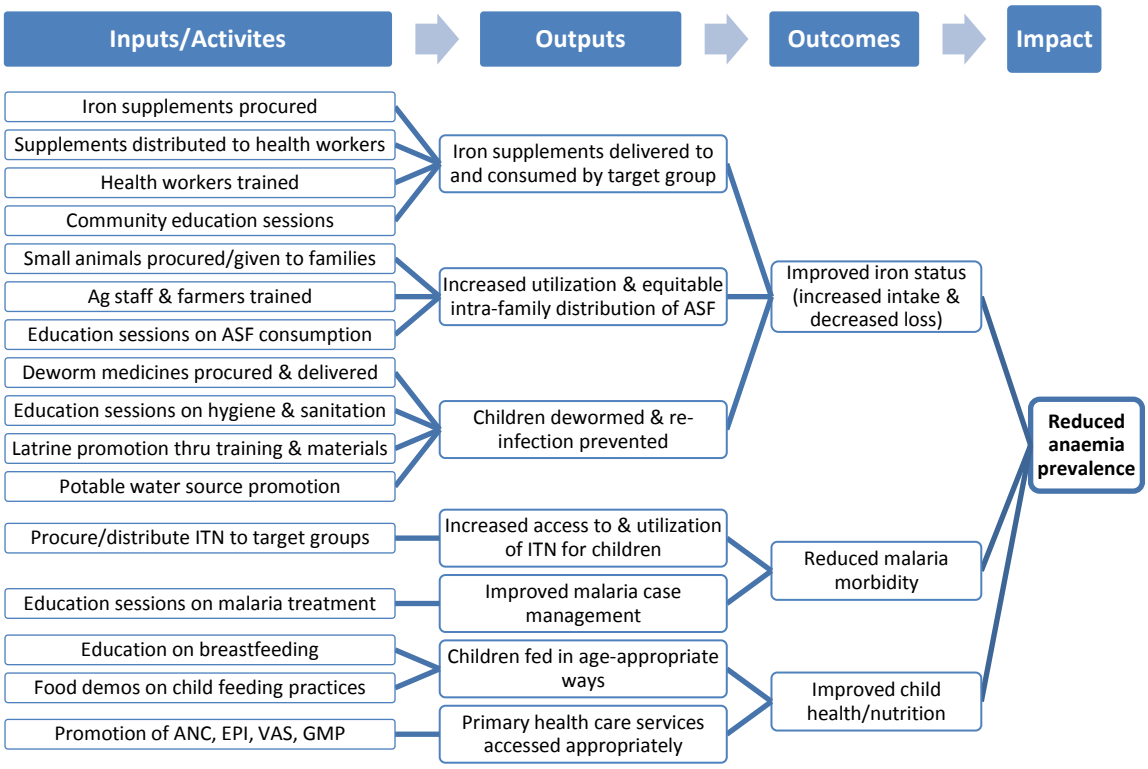



Figure 3.9: MICAH program logic diagram for the reduction of anaemia

Similarities across countries included the focus on training community health volunteers and establishing community-level committees to coordinate health and nutrition activities, utilization of existing health services to deliver nutrition education and other interventions, focus on underlying causes of morbidity (water/sanitation/hygiene, vitamin A supplementation) and intensified emphasis on malaria control in the second phase. A heavy reliance on program-trained community health volunteers was characteristic of all three program contexts.

### 3.3.1 Intervention description and level of reach

The MICAH program placed a high priority on monitoring of program activities and outcomes, an approach that was eventually termed "results based management". From the beginning of implementation, project staff collected data on the activities delivered by the program at all levels. A standardized list of process indicators was developed for the program as a whole and then customized for each country based on their specific interventions and approach. Data on these indicators were collected by various stakeholders (community health volunteers, health workers, and program staff) and collated on a quarterly basis for review by program staff and submission to the donor as part of quarterly progress reports. These data, along with the narratives that accompanied them in each report, will be used to describe in the following section, the intensity and reach of each country's anaemia-related interventions over time. A summary of the estimated intervention coverage achieved based on total target population for each country is presented in Appendix C.

#### 3.3.1.1 Iron supplementation

Iron supplementation was a major strategy for MICAH in all three countries to increase iron intake of children and women of reproductive age, including pregnant women. Building on existing national policies in each country for iron and folic acid supplementation targeted to women during pregnancy, the program introduced iron supplementation for additional target groups, including children 6-59 mo. Although Ghana and most projects in Malawi targeted children U5 with this intervention from the beginning, Tanzania initially focused on identifying anaemic children for treatment. However, following program evaluation survey results in 2000 that showed persistent high levels of anaemia among children U5 in Tanzania, the program introduced iron supplementation for children 6-59 mo in November 2002.

Distribution of the iron supplements for children U5 was community-based in Malawi, while in Ghana and Tanzania the distribution was both community and health institution based. The Malawi program developed a community-based system, with trained community health volunteers (CHV) distributing supplements on a weekly basis to adolescent girls, women of reproductive age and children 1-5 y of age. Compliance

was assured due to the fact that most children took the supplement in front of the volunteer. In Ghana, sub-district health staff were responsible for distributing the supplements every two months to all MICAH communities in their catchment area, usually during routine maternal and child health outreach services. CHV assisted them with mobilizing community members and followed up with home visits to ensure compliance. In Tanzania, iron tablets were given on a monthly basis to children through maternal and child health clinics and CHV. In all three countries, MICAH provided training for all involved and supported the delivery of education sessions on anaemia and iron supplementation by both health staff and CHV.

Each country distributed a different type of supplement for young children. Table 3.3 shows a comparison of the iron supplement protocols for children 24-59 mo across the three countries.

Table 3.3: Comparison of iron supplementation protocol for children 24-59 mo by country

| Country | Frequency | Type of supplement | Dose per week (mg) |
|---|---|---|---|
| Ghana | 2 d per week | Ferrous gluconate in multivitamin syrup [1] | 65-133 [2] |
| Malawi | Weekly | Ferrous sulphate tablet | 60 [3] |
| Tanzania | Weekly | Iron + folic acid | Not documented |

[1] Locally manufactured syrup also included (based on weekly dose of 65 mg ferrous gluconate): 3.5 mg vitamin B1, 0.5 mg vitamin B2, 25 mg nicotinamide, 100 mg liver extract and 100 mg calcium lactate.

[2] An increase in dosage from 65 to 133 mg per week was made towards the latter part of phase 2.

[3] Children also received 0.25 mg folic acid weekly.

Figure 3.10 shows a comparison of achieved coverage over time for iron supplementation to children U5 based on project quarterly monitoring figures. Coverage increased over time in phase 1 until early in 2002 in both Ghana and Malawi but decreased during the period of 2002-2003 when the program's second phase was being negotiated. Coverage in Tanzania in phase 2 was similar to that achieved by Ghana, reaching a maximum of about 45%. Malawi's coverage in the second phase remained below 20%. Using 2004 coverage levels as the numerator and the program's target reach as the denominator, Ghana achieved 65%, Malawi achieved 52% and Tanzania achieved 94% of their target reach. Program monitoring efforts included measures of compliance

in phase 2 only and this was documented as being very high – 99% in Ghana and 81% in Malawi. Based on household survey results in program areas in 2004, coverage achieved for child iron supplementation ranged from 26% in Tanzania (100% reported compliance) to 68% in Malawi (98.5% reported compliance) and 85% in Ghana (compliance not assessed).

In addition to iron supplementation, the program trained health workers in the recognition and treatment of anaemia, as well as provided treatment for anaemic children. In Tanzania, monitoring records showed a 12-fold increase in the number of children treated between the first and last year. When compared to estimated numbers of anaemic children in the targeted area, less than 10% of anaemic children were reached with treatment in the first phase but this improved dramatically in the second phase, increasing from 20% in 2003 to 72% in 2005.

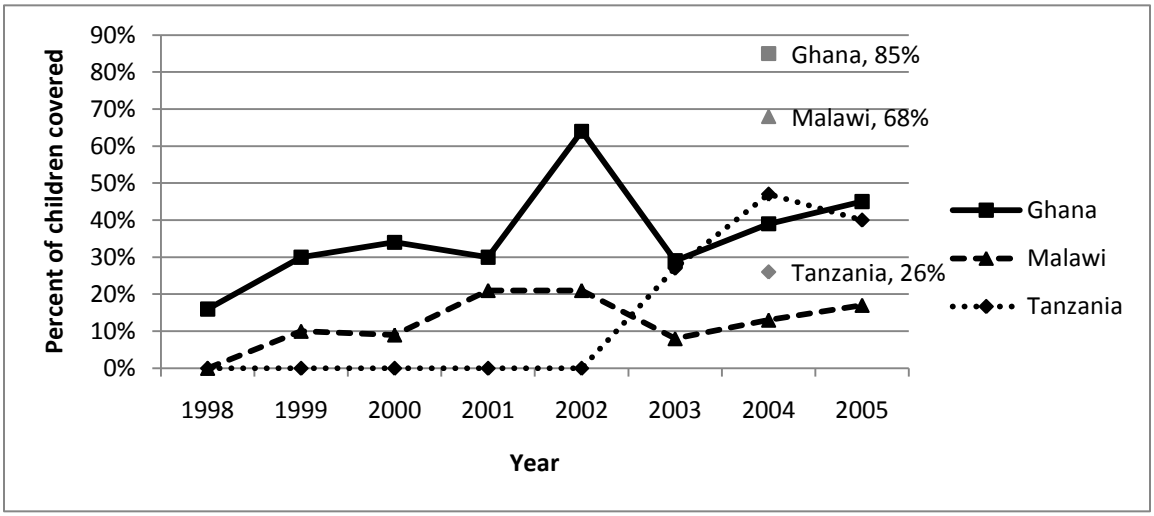



Figure 3.10: Comparison of iron supplementation coverage for children U5 by country based on program monitoring data from 1998-2005 (black markers) and household survey data in 2004 (grey markers)

### 3.3.1.2 Vitamin A supplementation

During the period of time under study, national policies and efforts to reach children 6-59 mo with semi-annual distributions of high-dose vitamin A supplements got underway in all three countries. In Ghana, the MICAH program began vitamin A

supplementation in 1998 prior to adoption by Ghana Health Service on a national level in 2000. District coverage for these campaigns frequently exceeded targets and they were believed to have reached the majority of eligible children. The one exception to this was very low coverage during a transition from campaign to routine health services delivery method in mid-2004, the period referenced by the MICAH survey in September 2004 (26%).

In Tanzania, the program supported the existing government distribution of vitamin A supplements to children U5 and postpartum women. During the first phase, the program negotiated for increased supplies of supplements to the districts and used community-based as well as periodic campaign-style distribution methods to increase coverage for children U5. Program reach for vitamin A supplementation among children U5 ranged from 40-67% prior to 2000 and then exceeded 85% in the last four years of implementation. The 2004 survey results showed similar levels of reach, as 83% of mothers reported that their child U5 had received vitamin A supplementation.

In Malawi, a decision was made by program stakeholders to support and promote vitamin A supplementation by UNICEF but not directly intervene themselves, in order to avoid duplication of effort. Thus, no monitoring or evaluation of this intervention was done by the program.

Programs in all three countries included community education sessions to explain the importance of participating in this activity. Programs in Ghana and Tanzania also sought to improve the vitamin A status of postpartum women and their infants through vitamin A supplementation following delivery at health facilities as well as from trained TBAs for women who delivered at home.

#### 3.3.1.3 Small-scale fortification

Small-scale fortification of maize flour with a multiple micronutrient premix was implemented in some MICAH program areas in Malawi and Tanzania. In Malawi, starting in 1998, the program worked in partnership with a local church organization in Domasi to equip their hammer mill operation to prepare fortified *likuni phala* (maize,

soybean and groundnut blend) for use in child feeding programs[13]. The program also initiated community-level fortification of maize flour at other local hammer mills in selected program areas in June 2001. The Domasi Fortification Unit prepared and distributed a premixed blend of maize flour and micronutrients to participating hammer mills. At these mills, one measured scoop of the premix blend was added to every 5 kg of maize and milled in traditional fashion. In phase 1, nine mills were fortifying maize flour, benefiting approximately 18,033 households. In phase 2, six partners implemented community fortification activities, reaching 23,842 households. By the end of 2005, 19 mills were fortifying maize flour and fortification acceptance rates were close to 100%.

In Tanzania, small-scale fortification of maize flour with a multiple micronutrient premix[14] was initially piloted in a few villages in one of the four program areas, beginning in August 2001. In the first year of implementing this activity, 11 out of 14 targeted villages benefited from hammer mill fortification at 23 sites, reaching approximately 23% of households. Early in phase 2, a decision was made to promote household-level fortification instead, due to the problem of frequent failure of the milling machines. Households were trained to add a 10g sachet of fortificant to 1 kg of maize flour prior to cooking. At this point, fortification activities were also expanded to communities in a second program area and by the final months of the program, 26% of all households reported fortifying their maize flour.

#### 3.3.1.4 Dietary diversification and modification

As a long-term strategy to address iron and other micronutrient deficiencies, all three country programs sought to increase household production and consumption of micronutrient-rich foods. Due to limits on the budget for these activities imposed by the donor, they were implemented as a demonstration activity, with a few individuals in selected communities provided inputs (seeds, seedlings, small animals) and training to

[13] The MICAH Malawi micronutrient premix was initially procured from Roche/DSM (South Africa) contained iron, folate, zinc, B-vitamins and vitamin A.

[14] The MICAH Tanzania micronutrient premix was obtained from the International Health and Food Association in Tanzania. Its contents were as follows (per 100 g of fortified maize meal): 10 mg iron (ferrous fumarate), 4 mg Vitamin A, 1.15 mg Vitamin B1, 0.45 mg Vitamin B2, 5 mg Vitamin B3, 1 μg vitamin B12, 0.1 mg folic acid, 30 mg vitamin C, 111 mg calcium.

initiate the activities. It was expected that these activities would diffuse to other community members through the 'pass on' concept.

Interventions included working with Ministry of Agriculture partners to introduce or reinforce local production of dark, green leafy vegetables (especially indigenous varieties) and vitamin A and C-rich fruits. The program supported community members in planting fruit trees and backyard, group and school gardens. In Malawi, solar driers were introduced as a best practice in preservation of fruits and vegetables, to provide a year-round source of micronutrients. Small animal rearing (rabbits, guinea fowl, goats and poultry) was also promoted in all three countries (only phase 2 in Ghana) as a means of increasing intake of animal source foods, especially meat and eggs. Management and follow-up of the repayment of animals by beneficiary households was the community's responsibility. Fish farming was also promoted by a few partner projects in Malawi and Tanzania.

All three country programs provided nutrition education for community members, including food demonstrations, on micronutrient-rich food sources and ways to enhance iron bioavailability from plant-based foods (e.g. eating citrus fruits after a meal). Emphasis was placed on how to use the produce from gardening activities in local dishes.

Although reports from all three countries suggest these activities were well-received by community members, participation was limited by program budget constraints for inputs and seasonal variability in growing conditions. Evidence for the intensity and reach of these activities is sparse and virtually no data are available on changes over time in the utilization or consumption of the intended products. In Ghana, program-supported gardening activities benefited 3-4% of program area households in the first phase while another 7-10% of households benefited from small animal training and inputs in phase 2. In Malawi, the small animal revolving fund distributed approximately 40,000 animals and an additional 15,213 animals were passed on to other households by 2005. Malawi survey results showed that the number of households with small livestock increased from 54% at baseline to 72% in phase 2. In Tanzania, a total of 29 school health clubs and 60 women's groups were formed in phase 1 and 605

households (about 4% of eligible) started gardening activities. In phase 2, about 10% of eligible households were documented as taking up vegetable gardening and 10% were reported to have started raising chickens.

#### 3.3.1.5 Infant and young child feeding practices

To improve infant and young child feeding practices, the MICAH program in all three countries promoted exclusive breastfeeding and appropriate complementary feeding practices through community education sessions for women and health staff training. In Ghana and Malawi, MICAH staff also worked with area health facilities to become Baby Friendly Institutions.

Although monitoring data suggest that only a small proportion of the target population attended breastfeeding and other child feeding education sessions, the program evaluation survey results showed an increase in the proportion of women exclusively breastfeeding for six months in all three countries. In Ghana, rates of exclusive breastfeeding for six months had improved from 20% at baseline to 31% in 2000 and 49% in 2004. In Malawi, this increased from 15% at baseline to 70% in 2004. The proportion of children exclusively breastfed for the first 3-4 months in Tanzania increased from 20% at baseline to 55 and 56% in 2000 and 2004, respectively.

Evidence for other changes over time in child feeding practices in program areas was limited. Program evaluation survey results showed little change in the types of complementary foods given to children. One exception was an increased frequency of feeding in 2004 in Tanzania, with 51% of infants in MICAH areas fed complementary foods three times per day compared to 35% in 2000.

#### 3.3.1.6 Water and sanitation

To improve access to safe water and reduce diarrheal diseases among children, MICAH programs in all three countries provided new or protected existing water sources, trained community water committees for water point maintenance and trained health workers and volunteers to deliver education sessions on water, sanitation and personal hygiene. In Tanzania, village artisans were trained in how to construct cement jars for rainwater harvesting. To improve access to sanitary facilities, the program

promoted the construction, utilization and maintenance of improved latrines. Other interventions included the promotion of community or household designated rubbish pits, clearing surroundings, use of utensil drying racks (Malawi and Tanzania), decanting small pools of water (Ghana), and constructing soakaways for waste water from bathrooms (Ghana). In Tanzania, approximately one quarter of all households were visited each year by village health workers to assess the level of environmental sanitation and provide education on disease prevention.

Program monitoring data show that 45 new or rehabilitated boreholes were provided by the program in Ghana. In Malawi, 387 new safe water sites were established in phase 1 and 124 boreholes were rehabilitated and 30 shallow wells protected in phase 2. Efforts to provide additional water sources in Tanzania resulted in the construction of three earth dams and five shallow wells in phase 1 as well as the protection of 10 springs; in phase 2, 23 additional water sources were provided. With regard to latrine construction, over 2,902 pit latrines were constructed in Malawi over the life of the program. In Tanzania, 785 latrines were built in the first phase and this activity benefited approximately 65% of eligible households in the second phase.

In all three countries, an increase over the program period was observed in the proportion of households with access to potable water sources. Access improved between 1996/1997 and 2004 from 54% to 79% in Ghana, from 55% to 81% in Malawi and from 39% to 47% in Tanzania. Malawi program documents report that the effect of these activities was the virtual elimination of cholera cases in program areas. However, in terms of the proportion of households reporting access to sanitary facilities, only Malawi program areas showed evidence of an increase over time (from 49% to 94%). This proportion stayed constant over time in Ghana at approximately 90% and from 69-75% in Tanzania.

#### 3.3.1.7 Disease control

To enhance the control of common diseases, including malaria and other parasitic infections, programs invested in a variety of treatment and prevention interventions. In Ghana and Malawi, mass deworming of children U5 by government health staff was implemented every six months. In Tanzania, preschool children were

treated through existing health units and mobile services. Deworming coverage estimates for children U5 fluctuated throughout the program period in all countries, ranging from 10-54% of eligible children.

To combat malaria, all three countries worked with communities to train and equip malaria control committees who then helped to coordinate and monitor malaria prevention activities. MICAH program efforts in the second phase were complemented by National Roll Back Malaria programs and changes in policy, such as the introduction of intermittent preventive treatment for pregnant women, resulted in new areas of emphasis in all three countries. The promotion and distribution of ITNs was another key component of malaria control strategies. Over the course of the program, approximately 2,668 ITN were distributed in Ghana, over 19,000 in Tanzania and approximately 96,926 in Malawi program areas. In Malawi and Tanzania, the projects established village ITN revolving funds in an effort to ensure sustainable access.

In addition, programs provided education sessions on the prevention and control of parasitic infections and malaria, the proper treatment of diarrhoea and the importance of seeking treatment promptly for sick children. Health workers were trained to better recognize the signs of dehydration and identify parasites for appropriate treatment. All three country programs provided cold chain equipment and logistical support for increased routine immunization coverage. In Malawi, MICAH projects provided various medicines for treatment and established village drug revolving funds to promote community-level access to these essential drugs at a low cost. A total of 65 drug revolving funds were established in phase 1 and an additional 177 in phase 2.

#### 3.3.1.8 Capacity building

MICAH sought to build the capacity of government and other development stakeholders to address micronutrient issues through strengthening the health system, providing health worker training and skills upgrading, and delivering community nutrition and health education activities to promote long-term behaviour change. Training for health staff and CHV focused on optimal diet and child feeding practices, growth monitoring and record keeping, recognition of micronutrient deficiencies and home horticulture. Other resource persons who benefited from MICAH capacity

building initiatives included traditional birth attendants, traditional healers, community health committee members and other local leaders.

Policy and advocacy work was an important part of ensuring that anaemia control efforts would be sustained. In Malawi, the program's support for the creation of a National Micronutrient Coordinator position was an effective way to ensure the experiences from MICAH and data collected were used to advocate for improvement to or implementation of government policies.

### 3.3.2 Summary of program reach

Based on the above review of program design and implementation, differences in program scope and reach are evident. The program's planned reach for anaemia-related activities was not 100% for any of the target groups in any of the countries. The rationale for this strategy is not well-documented and the characteristics of those not reached by the programs in each country are not known. In terms of activities directly targeted to children U5 (iron supplementation and deworming), the product of calculating the proportion of eligible children targeted overall and the quarterly program coverage targets shows that the expected reach was approximately 60% in Ghana, 50% in Tanzania and 25% in Malawi. Given this broad spectrum of intensity, it is expected that differences in child health and nutrition outcomes across country contexts would be observed.

# CHAPTER 4: RATIONALE AND RESEARCH OBJECTIVES

# 4 Rationale and Research Objectives

## 4.1 Rationale

The challenge of reducing anaemia levels among young children in Africa remains, despite decades of research seeking to understand its aetiology and develop effective interventions to reduce its prevalence and consequences. As summarized, there is abundant evidence on the individual risk factors for anaemia in young children, including factors related to both poor nutrition and poor health. Yet the causes of anaemia vary across geographic and socioeconomic contexts, therefore requiring that the context-specific causes be identified in order to inform decision-makers on the appropriate and most effective measures to be taken to prevent and control anaemia (De Benoist *et al.*, 2008).

What is also important to understand from a policy and program decision-making perspective is whether changes occur over time in the relationship between known risk factors and anaemia. In contexts where public health and nutrition programs are directly or indirectly intervening and having an effect on immediate and underlying causes of anaemia, the prevalence of anaemia is expected to decrease. What is not known is whether the risk relationships for the causes of anaemia also change over time in this type of program setting. Numerous cross-sectional studies have provided insights on the risk factors for anaemia at one point in time in specific contexts, but few have monitored this over time in order to provide evidence of their evolution.

The MICronutrient And Health (MICAH) program presents us with an opportunity to study the evolution that occurred in the prevalence of anaemia among young children over time in three different contexts where children and their families benefited from a package of anaemia control activities. Given the high prevalence of anaemia, and its posited similar aetiology, among young children in Ghana, Malawi and Tanzania, a similar set of strategies was used in these countries. Changes over time in child nutrition and health status were also evaluated in a similar manner. While the geographic scope of each country program varied, the length (8-9 years) and breadth of

activities in targeted communities were very similar. Therefore, it is expected that analyzing data from the MICAH program effort in these three countries will enhance our understanding of the dynamics of anaemia determinants across time and place in young children.

The present analytic work will focus on the problem of anaemia in children 24-59 months of age. There are well-documented differences across age groups in anaemia prevalence and associated risk factors (McElroy *et al.*, 2000; Stoltzfus *et al.*, 2000). The health and nutrition status of children 24-59 mo is relatively stable and expected to show evidence of the cumulative effect of their environment, including the program interventions and the various risk factors for anaemia during the earlier two years of development. By comparing cross-sectional survey data of independent groups of children 24-59 months of age collected four years apart in the same communities, we may be able to assess some of the relationships between the children's environment and the presence of anaemia, part of which is likely to reflect their environment since birth. While choosing a cut-off at ≥24 mo is somewhat arbitrary, it is consistent with current international nutrition program guidelines and previous evaluation efforts (Ruel *et al.*, 2008).

The importance and relevance of analyzing the risk factors for anaemia at different levels of anaemia severity are as follows. Historically, analytical studies and population surveillance on anaemia have tended to focus on the prevalence of all anaemia (Hb <110 g/L in children U5) and severe anaemia (Hb <70 or 50 g/L). Yet the public health consequences of moderate anaemia are significant and those of mild anaemia are beginning to be documented. Children in contexts with limited food sources of iron and frequent infection may regularly transition between a "normal" and mildly anaemic state. Mild iron-deficiency anaemia affects cognitive capacity in children and reduces aerobic work capacity in all individuals (Haas & Brownlie, 2001). Moderate and severe anaemia are associated with more serious functional consequences (Brabin *et al.*, 2001). Differentiating between mild and moderate/severe anaemia is important also for monitoring progress in anaemia control. As illustrated by Stoltzfus (1997), accurate assessments of the population burden of iron-deficiency anaemia must examine the lower end of the distribution of haemoglobin concentrations. Using a lower cut-off to

represent moderate-to-severe anaemia can reveal dramatic differences in the severity of anaemia in specific population groups. This has implications both for program impact evaluations as well as for public health policy.

## 4.2 Theoretical framework

Despite the multi-factorial causes of anaemia and its global significance as a public health problem, there are few conceptual frameworks in the literature that describe the relationships among its determinants. Research to date has utilized conceptual frameworks that specifically model the determinants of iron deficiency anaemia (Stephenson *et al.*, 2000b; Ben Rayana *et al.*, 2002). More recently, Ngnie-Teta et al. (2007) presented a multi-level conceptual framework for the sociodemographic determinants of anaemia among children in Benin and Mali, separating individual and household factors from contextual factors. In addition, since the causes of anaemia in young children in developing countries so closely parallel the causes of child malnutrition and mortality, more general models also may be seen as useful guides in this research.

A key characteristic to be considered in the selection of a conceptual framework for the determinants of child anaemia is that it brings together the social and economic determinants with the biological, or more proximal, determinants. As the analytical framework by Mosley and Chen (1984) depicted, socioeconomic and cultural variables operate through a limited set of proximate determinants that directly influence the risk of disease and the outcome of disease processes. The transitory nature of illness and health in this framework parallels the continuum of anaemia states in young children in contexts with limited food sources of iron and frequent infection, since they may regularly transition between “normal”, mild and moderate to severe anaemia states.

For the purposes of this study, the UNICEF conceptual framework of the causes of malnutrition (1990) is useful in terms of its conceptual similarity to the causes of anaemia, particularly in terms of identifying nutritional status and morbidity as the two immediate causes of malnutrition, which are in turn determined by a set of underlying and basic causes. Anaemia in young children can also be conceptualized as the direct

outcome of undernutrition and morbidity, as well as their synergistic effect. A modified version of the UNICEF conceptual framework is presented in Figure 4.1, to visually depict these relationships.

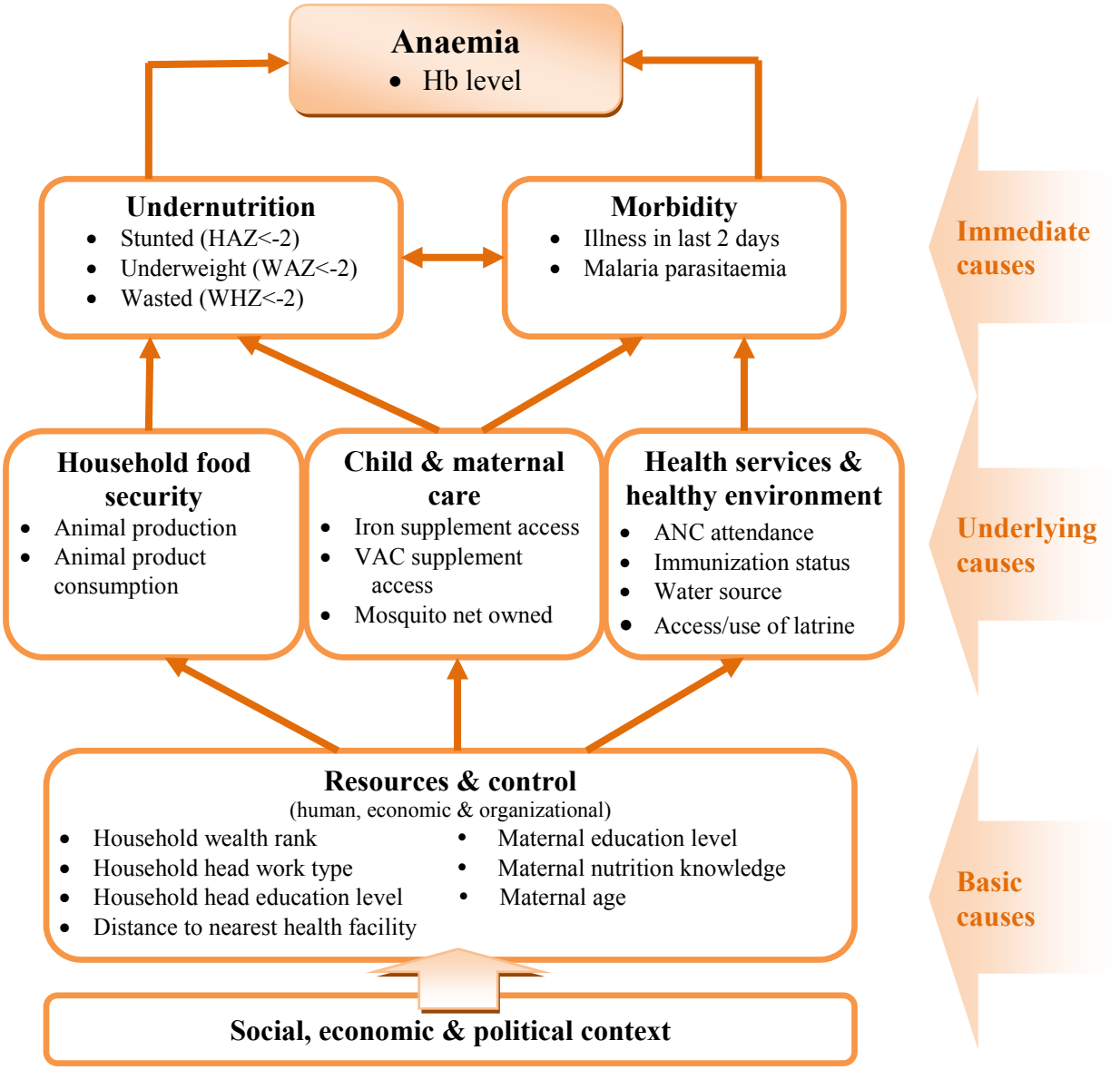



Figure 4.1: Theoretical framework (Adapted from UNICEF, 1990)

Undernutrition occurs, in large part, as a result of inadequate dietary intake, including low iron content and bioavailability. Children with growth faltering often have experienced inadequate nutritional intake compared to their requirements and this increases the risk of iron deficiency anaemia, along with other nutrient deficiencies

(McElroy *et al.*, 1999). For the purposes of this study, undernutrition is measured by child anthropometry. Specifically, a child's stunting status (height-for-age z-score <-2 SD), a measure of chronic undernutrition, is used since it captures the cumulative effects of dietary inadequacy and multiple constraints to health. While additional, more specific measures of micronutrient intake and status, especially iron intake and iron status, would also be useful in characterizing the nutritional status of each child, these were not available in the MICAH data sets.

Parasitic and other infections also directly cause anaemia in children, either through destruction of red blood cells as occurs during malaria episodes or through the body's inflammatory response and its effect on erythropoeisis and iron metabolism. Malaria parasitaemia and reported child illness in the past two days provide two standard measures of morbidity in this analysis. While soil-transmitted helminth infections are also an important factor in the causal pathway of child anaemia in some contexts, data were not available on helminth infection or deworming status (a potential proxy for helminth infection) for children in this study.

Underlying both malnutrition and morbidity are risk factors related to household food insecurity, inadequate child care and feeding practices, unhealthy household environments and inadequate health services. These underlying causes are the focus of most public health and nutrition program interventions seeking to improve individual and collective health-promoting behaviours and increase household access to healthy foods, healthy environments and quality health services. While improvements at this level have been shown to improve child nutritional and health status, there is, however, little evidence for a direct impact of changes in these factors on anaemia levels. Measures of household animal source food production and consumption, access to micronutrient supplementation for children, ownership of mosquito nets, antenatal care attendance, child immunization status, access to potable water source and type of toilet used, function as indicators of these underlying risk factors for anaemia on which the MICAH program acted directly.

Ultimately, the causes of anaemia, malnutrition and morbidity are a function of the social, economic and political context in which these children and their families live.

Pervasive poverty limits the capacity of families to purchase or produce food, and lack of education and inappropriate cultural beliefs result in poor child feeding, caring and health care-seeking practices. In this analysis, the lack of financial, human, physical, social and natural capital required for child well-being is considered as a basic, fundamental cause of anaemia that influences the direct relationships between malnutrition, morbidity and anaemia. As Mosley and Chen's (1984) framework described, these include individual, household and community level factors. In this study, measures of household relative wealth rank, household head occupation and education level, maternal education level, nutrition knowledge and age, and distance of the household to the nearest health facility will be used as proxy indicators of these complex factors.

In addition to these direct causal relationships, the model also depicts the synergistic interaction between child undernutrition and morbidity, a well-documented relationship that is highly relevant to the analysis of risk factors for anaemia (Scrimshaw & SanGiovanni, 1997). Illness has an effect on dietary intake, which in turn compromises nutritional status and affects the body's response to the illness, such as increased vulnerability to progression from infection to disease. This synergism is a common cause of iron and other micronutrient deficiencies, which in turn directly contribute to the prevalence of anaemia in young children. Children with mild to moderate malnutrition show impaired immunocompetence and tend to have more severe and longer duration infections than healthy children (Martorell & Ho, 1984), putting them at increased risk of anaemia as a result. Malaria and intestinal parasites adversely influence nutrition by limiting food intake through anorexia and vomiting. The inflammation associated with subclinical and clinical infections alters nutrient absorption and utilization (Thurnham & Northrop-Clewes, 2007). Young children who experience recurrent malaria episodes fail to gain weight, have retarded growth and show evidence of impaired cognitive development (Bates *et al.*, 2004b).

One could also argue that the synergistic interaction between undernutrition and morbidity acts in ways that increase child vulnerability. Although early childhood is a period of heightened vulnerability overall (Martorell, 1999) and children are often considered "vulnerable" as a group in the population, the concept of vulnerability also

has a broader meaning. Chambers (1989) states: "Vulnerability refers to exposure to contingencies and stress and means for coping with them. Vulnerability thus has two sides: an external side of risks, shocks and stress to which an individual or household is subject and an internal side which is the means for coping without damaging loss." From a public health nutrition perspective, the external side of vulnerability refers to the exposure that a child experiences to deficits in micronutrient-rich foods, infectious diseases and inadequate health care. The child's household and community are also exposed to stresses such as seasonal or chronic food insecurity, economic constraints, inadequate health or other infrastructure, environmental degradation and periodic shocks such as floods or drought. The internal side of vulnerability can be viewed as the resilience of individuals, households and communities, i.e. their capacity to cope with, recover from and adapt to these risks, stresses and shocks. An undernourished child with compromised immunity has less capacity than an adequately nourished child to resist infection following exposure to a pathogen and is slower to recover.

This study is interested in taking the concept of vulnerability another step further in the field of public health nutrition and looking at ways in which multiple, integrated program interventions may act at multiple levels to enhance capacity and reduce vulnerability. In particular, this study is designed to explore how multiple interventions that simultaneously address the immediate, underlying and basic causes of anaemia may modify these risk relationships and influence a child's response when exposed to these risk factors.

In developing country contexts, early childhood is a period of high exposure to external stressors. As described earlier, young children have increased vulnerability to iron deficiency during the early weaning period and also must cope with seasonal variation in childhood diseases (Brewster & Greenwood, 1993) and micronutrient-rich food availability (Mensah & Tomkins, 2003). These children are often considered "vulnerable" due to the fact that they are more likely to be harmed by these stressors than others in the general population (Galea *et al.*, 2005). However, a wide range of factors contribute to the variation observed in the impact of disease between different communities and individuals. These include individual factors such as biological immunity, household factors such as caregiver knowledge and institutional factors such

as adequacy of health services (Bates *et al.*, 2004b). Children may be exposed to similar stressors or risk factors but their capacity to respond to and recover from that exposure is influenced to a large degree by various factors that work together in complex ways to either increase or reduce their vulnerability.

A recent study explored the effects of social inequities on the health and nutrition of children in low and middle income countries, applying the concepts of differential exposure and vulnerability (Barros *et al.*, 2010). The results showed that children from poor households are at consistently higher risk of exposure to risk factors for disease, such as inadequate water and sanitation and lower use by caregivers of disease prevention practices, such as hand washing. Poverty was also associated with how vulnerable children are to disease as a result of exposure, both in terms of incidence and severity. Factors affecting disease incidence included child feeding practices, antenatal care and use of mosquito nets to prevent malaria. Factors affecting disease severity included the child's overall nutritional status, specific nutrient deficiencies, and coverage of effective curative interventions.

With an understanding of how exposure (whether to risk factors such as infectious agents or to protective events such as deworming campaigns) interacts with underlying capacities to shape child vulnerability at any particular point in time (Galea *et al.*, 2005), it is possible to hypothesize the expected impact of an intervention or multiple interventions over time. Anaemia control programs often seek to reduce child exposure to risk factors such as iron deficient diets or malaria. However, even without reducing the level of child exposure to immediate causes of anaemia, an intervention may be able to change the risk relationship between exposure and effect by enhancing capacity to respond through addressing the underlying and basic causes at the household, community and/or institutional levels, thus reducing vulnerability. A good example of this is the study by Kidane and Morrow (2000) in which the risk relationship between malaria and mortality changed in intervention communities as a result of teaching mothers with low education levels how to take care of their sick children and supplying them with appropriate drugs for home medication. In this case, the intervention reduced the vulnerability of these children to malaria-related mortality by acting at both the household capacity level (knowledge of mothers) and the

institutional/systemic capacity level (access to malaria medication), without changing the level of exposure of the children to malaria infection.

In MICAH program areas, the delivery of a package of integrated health and nutrition interventions was expected to have a similar buffering effect on the risk of anaemia associated with undernutrition and morbidity, in addition to acting on the prevalence of risk factors. By intervening at multiple levels within the causal pathway, the program was designed to enhance the capacity to respond of children, their households and communities, as well as the broader system within which they live. This was expected to reduce child vulnerability to anaemia, regardless of the level of exposure to known risk factors for anaemia.

## 4.3 Research objectives and hypotheses

The overarching purpose of this research is to understand better the variation over time of anaemia and its risk factors among young children in areas of Ghana, Malawi and Tanzania benefiting from an integrated health and nutrition program. Building on a description of the MICAH program that documents the specificity of each country's approach to addressing anaemia in children and how this developed over time, this research seeks to address the following specific objectives and test their accompanying hypotheses.

**Objective 1: To describe how the prevalence of anaemia evolved among children 24-59 mo in three countries in areas benefiting from integrated health and nutrition interventions.**

Although the program evaluation results showed an overall decrease in anaemia among children 6-59 mo in two of the three countries (Berti *et al.*, 2010), this analysis will focus on the differences between 2000 and 2004 in the prevalence of mild and moderate/severe anaemia in children 24-59 mo.

**Hypothesis:**

- A lower prevalence of overall anaemia (Hb <110 g/L) among children 24-59 mo in 2004 compared to 2000 will be accompanied by a lower prevalence of

moderate/severe anaemia and higher prevalence of mild anaemia, given the high prevalence of anaemia in each country in 2000.

**Objective 2: To determine whether the risk of mild and moderate/severe anaemia and lower mean haemoglobin associated with known risk factors differed between 2000 and 2004 for children 24-59 mo living in areas benefiting from integrated health and nutrition interventions.**

In the interest of understanding any variation that occurred between countries and time points in the relationship of various risk factors to mild and moderate/severe anaemia, this analysis will examine the risk factors associated with anaemia severity in each country and with mean haemoglobin levels overall. Based on the theoretical framework, any variation in the risk associated with underlying and basic causes of anaemia is expected to operate primarily through the immediate causes of undernutrition and morbidity. Therefore, the analysis will test for evidence of variation between 2000 and 2004 in the strength of the risk of anaemia associated with stunting, malaria and recent illness and in the estimates of the proportion of risk attributable to these causes.

**Hypotheses:**

- The risk of mild and moderate/severe anaemia (and lower mean haemoglobin) associated with malnutrition (as measured by stunting) and morbidity (as measured by malaria parasitaemia and recent illness) will be lower in 2004 compared to 2000 (when adjusted for potential confounding factors) in the context of health and nutrition interventions that are improving the underlying causes of these factors and decreasing vulnerability of children to their negative effects.
- The fraction of anaemia risk attributable to immediate causes (malnutrition and morbidity) will decrease between 2000 and 2004.

Given these research objectives and their associated hypotheses, the next section provides details on the methods utilized to address them.

# CHAPTER 5: METHODS

# 5 Methods

Building on the description of the MICAH program context in Chapter 3, this section provides a detailed description of the methods of quantitative data analysis undertaken with the goal of describing the characteristics of children 24-59 mo in MICAH program areas of Ghana, Malawi and Tanzania. The program evaluation design and methods used to collect the data will be outlined for each country. The definition and basis for the variables used in the analysis will be elaborated and the statistical analysis performed will be described.

## 5.1 Data sources

Household survey data collected during the MICAH program evaluations in each country will be used to address the research objectives related to the change in anaemia over time and its associated risk factors. The program used a repeated cross-sectional evaluation design with household surveys conducted in program-targeted communities before and after the two phases of intervention in all countries. Baseline assessments were conducted in October to December 1996 in Malawi, September to October 1997 in Ghana and December 1997 to January 1998 in Tanzania. Subsequent surveys were carried out at the same time of year in 2000 and 2004 in order to evaluate the impact of the program in these areas.

The baseline and evaluation surveys were designed using the MICAH Guide, a handbook developed by World Vision Canada to standardize the design, monitoring and evaluation of micronutrient programs (1996). The household survey guidelines were based, in large part, on UNICEF's handbook for multiple indicator cluster surveys (UNICEF, 1995). The objectives for each survey were to measure key indicators related to household characteristics, knowledge, attitudes and practices associated with micronutrients and health, and measures of health and nutritional status among children and women.

In an effort to strengthen the design and assess with greater certainty whether the program was truly having an effect, a sample of comparison communities were included

in the 2000 survey in Ghana and Malawi and in the 2004 survey in all three countries. Sampling methods for these areas were inconsistent across countries and documentation regarding their characteristics was sparse; therefore, data from these comparison areas were not included in this study.

### 5.1.1 Survey sample

All three countries used two-stage cluster sampling with stratified probability sampling (probability proportional to size) methods, as outlined in the MICAH Guide (World Vision Canada, 1996). However, the sample size calculation and cluster selection process were slightly different in each country and is described in detail below.

#### 5.1.1.1 Ghana

In Ghana, the 2000 and 2004 surveys were conducted in a similar manner to the baseline survey. The baseline survey sample size of 1000 households was based on an estimate given in the MICAH Guide that suggested that "a sample of 500 to 1000 households allows for 'estimation of coverage' goals with a margin of error of 5 percentage points or less. It will usually be adequate for baseline estimates for future comparisons of data from a repeat survey" (World Vision Canada, 1996, p.2). Using a standard cluster survey sample size calculation (Magnani, 1997), a sample of 1,000 households would allow for detection of a 12% decrease in anaemia among children U5 (assuming an initial prevalence between 50-80%), with a confidence level of 95% and 80% power, including a design effect of 2.

Two-stage stratified probability sampling methods were used. The first stage involved listing the number of communities and their populations for each of the eight subdistricts where the program planned to intervene. Although the exact manner in which the clusters were selected is unclear, a total of 20 communities were randomly selected at baseline, as shown in Table 5.1, and these same clusters were used for all subsequent surveys. In 2004, an additional 10 program clusters were included, selected randomly from a group of 60 communities where intervention activities started later in the first phase. The second stage of sampling was done at the community level on the first day of data collection. All eligible households in each community (cluster) were

enumerated and then the required number of households (50 in 2000 and 30 in 2004) was selected using simple random sampling.

Table 5.1: MICAH Ghana baseline survey sampling frame

| **Sub-district** | **Sub-district population** | **No. of communities** | **Number of clusters** | |
|---|---|---|---|---|
| | | | **Baseline & 2000** | **2004** |
| Mpraeso | 45,797 | 46 | 3 | 3 |
| Nkawkaw East | 40,697 | 30 | 2 | 2 |
| Nkawkaw West | 54,521 | 66 | 2 | 3 |
| Kwahu Praso | 21,974 | 110 | 4 | 8 |
| Pepease | 34,423 | 110 | 3 | 6 |
| Abetifi | 18,899 | 120 | 2 | 2 |
| Nkyenekyene | 30,398 | 130 | 2 | 3 |
| Kwahu Tafo | 33,648 | 138 | 2 | 3 |
| **TOTAL** | **280,357** | **750** | **20** | **30** |
| **Households per cluster** | | | 50 | 30 |
| **Desired sample size (households)** | | | 1000 | 900 |
| **Actual sample size (% of desired)** | | | 1000 (100%) | 900 (100%) |

#### 5.1.1.2 Malawi

In Malawi, the 2000 survey sample size was calculated using EpiInfo 6.1 (StatCalc program) using a 95% confidence interval, power of 80% and a design effect of two to account for cluster sampling. After calculating the minimum sample size required for all key program indicators, the indicator that required the largest sample size was anaemia prevalence in pregnant women. Based on an estimated decrease in prevalence from 50% to 40%, plus an additional 10% to account for non-responders, a sample size of 695 pregnant women was calculated. Assuming pregnant women represented 5% of the population and there were an average of six people per household, a sample of 2,320 households was calculated. A similar sample size was targeted in 2004 (2,091 households) but the number of clusters was increased from 48 in 2000 to 119 in 2004.

In both years, the sampling frame listed all villages within the project intervention areas and their population size. Based on the desired number of clusters (defined as villages: 48 in 2000 and 119 in 2004), villages were randomly selected using probability proportional to size. A list of the clusters and number of households selected within each cluster is shown in Table 5.2.

The selection of households within each cluster/village was carried out using systematic random sampling, based on a list of the households in the village that was made on the day of the interviews and the total number of households to be interviewed in that village. If no woman of childbearing age and/or child U5 lived in a selected household, the interviewer went to a substitute household, also chosen at random. Enumerators did not know if it was a project or comparison village.

Table 5.2: MICAH Malawi survey sample summary

| District and project by region | | 2000 | | | 2004 | | |
|---|---|---|---|---|---|---|---|
| | | | Households | | | Households | |
| | | Clusters | Per cluster | Total | Clusters | Per cluster | Total |
| **Northern Region** | | | | | | | |
| Chitipa | Karonga ADD | 2 | 56-69 | 127 | 6 | 6-41 | 115 |
| | CHSU | 2 | 14-24 | 39 | 7 | 3-30 | 77 |
| | Namatubi ADP | 0 | -- | 0 | 4 | 5-30 | 57 |
| Rumphi | Rumphi-MOH | 6 | 15-112 | 281 | 5 | 7-13 | 45 |
| Mzimba | Ekwendeni | 3 | 10-32 | 56 | 5 | 4-15 | 49 |
| **Central Region** | | | | | | | |
| Lilongwe | Chata | 2 | 12-18 | 30 | 11 | 5-20 | 141 |
| | Kabudula | 1 | 16 | 16 | 5 | 3-8 | 27 |
| | St Gabriel Kalolo | 1 | 22 | 22 | 11 | 3-78 | 260 |
| Mchinji | St Gabriel/Mavwere | 1 | 28 | 28 | 10 | 6-58 | 241 |
| Dedza | Salima ADD | 1 | 32 | 32 | 4 | 8-41 | 85 |
| | Mua | 1 | 72 | 72 | 4 | 12-35 | 86 |
| Ntcheu | Africare | 5 | 18-54 | 180 | 0 | -- | 0 |
| | Senzani | 1 | 26 | 26 | 11 | 7-32 | 149 |
| **Southern Region** | | | | | | | |
| Balaka | Emmanuel | 2 | 36-38 | 74 | 0 | -- | 0 |
| Machinga | Machinga ADD | 2 | 66-93 | 159 | 4 | 12-36 | 105 |
| Mangochi | CHSU | 5 | 60-163 | 492 | 8 | 15-43 | 195 |
| Chiradzulu | Chitera | 4 | 26-78 | 194 | 5 | 4-20 | 52 |
| Zomba | Domasi | 1 | 25 | 28 | 10 | 5-25 | 126 |
| Mulanje | Ntiza | 4 | 40-115 | 272 | 8 | 6-31 | 127 |
| Chikwawa | IEF | 4 | 23-47 | 172 | 0 | | 0 |
| **Total actual sample size** | | **48** | | **2300** | **118** | | **1937** |
| Desired sample size | | | | 2320 | | | 2091 |
| Actual proportion sampled | | | | 99% | | | 93% |

### 5.1.1.3 Tanzania

The Tanzania baseline survey sample size was calculated based on the estimated prevalence of stunting (55%) in the intervention area, obtained from the DHS 1996 results for Tanga Region. Assuming a sampling error of ±3% and confidence level of 95%, a sample size of 1100 was obtained using the formula, $N=(t^2 * p(100-0))/d^2$, where N=sample size; t=probability that the true prevalence of stunting is within the chosen value of d (t=1.96, rounded to 2 in field calculation); p=estimate of prevalence of stunting in the area (55%); and d=level of precision (±3%). The sample size was increased by 15% to account for potential non-responders, resulting in a final sample size estimate of 1265 households. The 2000 and 2004 surveys were conducted using approximately the same sample size.

For the sampling frame, the number of households to be surveyed was divided between the four divisions proportionately to the division's population, as shown in Table 5.3. Clusters were defined as villages and a sampling frame was developed with a list of all villages in each division. Simple random sampling was used to select the required number of villages (clusters) in each division. The second stage of sampling involved randomly selecting households within each selected village. Although the same clusters were used for both surveys in program intervention areas, households within these clusters were selected at random during each survey. Only households with a child under five years of age were included as sampling units in 2000 and 2004.

Table 5.3: MICAH Tanzania survey sampling frame

| **District** | **Division** | **Division Population** | **Clusters (Villages)** | **Households** | |
|---|---|---|---|---|---|
| | | | | **2000** | **2004** |
| Handeni | Mazingara | 26,145 | 3 | 186 | 178 |
| | Sindeni | 30,000 | 3 | 232 | 206 |
| | Mzundu | 52,000 | 4 | 342 | 308 |
| Korogwe | Mombo | 89,622 | 8 | 535 | 612 |
| **Total sample size** | | **197,767** | **18** | **1295** | **1304** |
| Desired sample size | | | | 1265 | 1265 |
| Actual proportion sampled | | | | 102% | 103% |

### 5.1.2 Data collection instruments

Survey data collection consisted of three components – a household interview, biochemical sample collection and clinical examination, including anthropometric measurements. Household interviews were conducted in-person using a standardized questionnaire from the MICAH Guide (see Appendix D), developed by a group of technical experts. Contextualization of the questionnaire occurred in each country and the revised and translated versions were pre-tested prior to data collection. The questionnaire was structured as a combination of modules, with core modules that were administered to every household and others designed to be administered only to specific target groups that may be present in the household (e.g. a pregnant woman). A description of the standard modules relevant to this study is given in Table 5.4. Revisions were made to the survey questionnaire in 2000 and 2004; the main changes involved adding indicators related to program interventions.

Biochemical samples were collected for a sub-sample of specific target groups randomly selected from households interviewed, using the household member listing as a guide to the presence of eligible members. Laboratory technicians were responsible for collecting blood samples. Haemoglobin concentration was measured in g/L using capillary blood samples dropped onto microcuvettes and analyzed immediately using a HemoCue B-Haemoglobin photometer (HemoCue AB, Angelholm, Sweden). Presence of malaria parasites was determined by thick blood smear stained with Geimsa stain.

Clinical examinations were conducted for all children less than five years of age by trained personnel. Height was measured to the nearest 0.1 cm using a height board (Malawi 2000 & 2004, Tanzania 2004), microtoise (wall chart, Ghana 2000 & 2004), or portable Harpenden stadiometer (Tanzania 2000) for children over two years and length was measured to the nearest 0.1 cm using locally manufactured length boards for children under two years of age. Weight was measured to the nearest 0.1 kilogram using calibrated Salter scales for all children in Ghana and Malawi, and children under two years in Tanzania; SECA electronic bathroom scales were used for children over two years in Tanzania.

Table 5.4: MICAH standard questionnaire modules description

| **Module** | **Target respondent** | **Sample measures** |
|---|---|---|
| Household characteristics | Household representative | Full household member listing (age, sex, education), assets, fuel type and roof material |
| Agriculture and food | Household representative | Land ownership, agricultural product use |
| Water and sanitation | Household representative | Water source, latrine utilization |
| Breastfeeding and weaning patterns | One mother of a child <5yrs; questions refer to her youngest child | Exclusive breastfeeding, timing and content of complementary feeding |
| Vitamin A knowledge, attitudes and practices | One mother of a child <5yrs; questions refer to oldest child <5yrs | 7-day food frequency questionnaire for vitamin A-rich foods, knowledge of night blindness and foods to prevent it, VAC supplementation |
| Iodine knowledge, attitudes and practices | One woman in the dwelling 15-49 years of age | Goitre awareness and prevention, iodized salt test |
| Iron knowledge, attitudes and practices | One mother of a child <5yrs | Anaemia awareness and prevention, ANC attendance, iron supplementation |
| Immunization, morbidity and anthropometry | Mother of child <5yrs; completed for all children <5yrs in the dwelling | Date of birth, birthweight, immunization records, weight, height, reported illness in last two weeks |

### 5.1.3 Data entry, cleaning and analysis

Following data collection, completed questionnaires were reviewed. Data entry was conducted by trained workers using EpiInfo version 6 (CDC, Atlanta GA). In each country, a proportion of questionnaires were double-entered and quality of data entry was assured at less than 5% error for key indicators. Data cleaning was conducted by program staff in collaboration with qualified and experienced statisticians in all three countries. Additional cleaning was performed by World Vision Canada. For the purposes of the current study, further cleaning and analysis were carried out using SPSS version 16.0 (SPSS, Inc., Chicago IL). In particular, the cleaning process required matching data between different modules in order to enable analysis of household and other characteristics for children with haemoglobin measurements.[15]

### 5.1.4 Ethical consideration

At the start of the MICAH program in each country, ethical consent was obtained from the Ministry of Health for conducting the planned activities, including the baseline and follow-up surveys. Before each survey was conducted, program staff contacted authorities in the area to inform them of the survey purpose and methods. Household members in the selected communities were informed about the purpose and benefits of voluntarily participating in the survey. Individual consent was sought at each selected household before the interview. No financial or material incentives were given to respondents or their children to participate in the survey. Treatment was given to all individuals who were tested and found to be positive for malaria, hookworm, schistosomiasis or anaemia.

This study is an analysis of publicly available data. Data access was granted by World Vision Canada on 23 April 2009.

[15] For the Malawi data, the additional cleaning was carried out by Alexander Kalimbira, a PhD student from University of Guelph who was using the data for his thesis.

## 5.2 Study sample

The study sample was limited to children between the age of 24 and 59 months with a haemoglobin measurement. In order to maximize the sample size and minimize sampling bias, initially all children meeting these criteria were selected. However, in approximately 10% of households, multiple children met these criteria. Therefore, one child was selected from each household for the current analysis. In addition to age and haemoglobin measurement, children were selected based on the criteria of complete anthropometric measurements within the biologically normal range [16], malaria parasitaemia data and data for all other key variables included in the final models. Where two or more children met these criteria in one household, the child for whom the food frequency questionnaire was answered was selected. Otherwise, the oldest eligible child was selected.

Table 5.5 summarizes the total number of households for which data were available, the number of children 24-59 mo with haemoglobin measurements and the resulting total number of children 24-59 mo meeting all eligibility criteria. The number of households included in each survey ranged from 900 in Ghana in 2004 to 2,300 in Malawi in 2000. Children 24-59 mo made up a similar proportion (11-14%) of household members across all data sets. However, due to differences in the number of children sampled for haemoglobin and malaria measurements, the proportion of children 24-59 meeting all selection criteria ranged widely: 41-48% in Ghana, 43-50% in Malawi and 8-67% in Tanzania. In particular, much smaller sub-samples of children were assessed for haemoglobin and malaria in Tanzania in 2004, resulting in a low proportion (8%) of children eligible for inclusion in this study.

[16] Excluded extreme z-scores, based on WHO Anthro Software guidelines (WHO, 2007b). The following lower and upper SD boundaries are the set flag limits for identifying any extreme or potentially incorrect z-score values for each indicator: WAZ (-6, +5); HAZ (-6, +6); WHZ (-5, +5).

Table 5.5: Summary of study samples selection in the three countries and at two time periods

| Sample unit | GHANA | | MALAWI | | TANZANIA | |
|---|---|---|---|---|---|---|
| | **2000** | **2004** | **2000** | **2004** | **2000** | **2004** |
| Clusters | 20 | 30 | 48 | 119 | 18 | 18 |
| Households per cluster | 50 | 30 | 10-163 | 3-78 | 20-133 | 22-120 |
| Households surveyed | 1,000 | 900 | 2,300 | 1,937 | 1,295 | 1,304 |
| *Households with child 24-59 mo* | *559* | *530* | *1,062* | *1,197* | *861* | *830* |
| Household members | 4,961 | 4,317 | 9,424 | 9,483 | 7,581 | 6,607 |
| Children 24-59 mo | 616 | 614 | 1077 | 1368 | 940 | 932 |
| (% of members) | (12%) | (14%) | (11%) | (14%) | (12%) | (14%) |
| Children 24-59 mo with Hb data | 366 | 338 | 690 | 893 | 818 | 247 |
| **Children 24-59 mo meeting all selection criteria** (% of children 24-59 mo) | **253** (41%) | **296** (48%) | **466** (43%) | **679** (50%) | **634** (67%) | **77** (8%) |

## 5.2.1 Comparison between study and excluded children

To determine whether the children 24-59 mo selected based on the above criteria were representative of all children 24-59 mo and those with haemoglobin measurements, the characteristics of children included in the study were compared with those excluded[17]. Table 5.6, Table 5.7 and Table 5.8 show the results of the comparison of child characteristics for each country and survey year. Comparisons for health and nutrition practices and household characteristics are shown in detail in Appendix E.

[17] Each household surveyed is only represented once across all samples of study and excluded children (with and without haemoglobin data). If more than one child from a household was excluded, the child with a haemoglobin measurement was selected for this analysis. If both children from a household were excluded and neither had a haemoglobin measurement, the first child enumerated was selected for this analysis.

Table 5.6: Characteristics of study and excluded children 24-59 mo by survey year, Ghana

| Characteristic | | 2000 | | | | | | | | 2004 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | |
| | | N | % | N | % | p-value[1] | N | % | p-value[2] | N | % | N | % | p-value[1] | N | % | p-value[2] |
| **Child characteristics** | | | | | | | | | | | | | | | | | |
| Anaemia, | Mild | 253 | 24.1 | | n/a | | 106 | 25.5 | 0.157 | 296 | 11.8 | | n/a | | 41 | 14.6 | 0.619 |
| | Moderate | | 34.0 | | | | | 43.4 | | | 17.2 | | | | | 12.2 | |
| | Severe | | 1.6 | | | | | 0 | | | 0.7 | | | | | 0 | |
| Age group | 24-35 mo | 253 | 41.5 | 185 | 29.2 | 0.030 | 106 | 29.2 | 0.062 | 296 | 39.2 | 191 | 26.2 | 0.012 | 41 | 26.8 | 0.118 |
| | 36-47 mo | | 32.4 | | 38.9 | | | 34.9 | | | 30.7 | | 36.6 | | | 46.3 | |
| | 48-59 mo | | 26.1 | | 31.9 | | | 35.8 | | | 30.1 | | 37.2 | | | 26.8 | |
| Male | | 253 | 51.0 | 185 | 51.9 | 0.852 | 106 | 49.1 | 0.738 | 296 | 54.1 | 191 | 49.7 | 0.315 | 41 | 39.0 | 0.065 |
| Stunted (HAZ<-2) | | 253 | 37.2 | 175 | 42.3 | 0.285 | 96 | 35.4 | 0.764 | 296 | 29.1 | 188 | 29.8 | 0.863 | 38 | 36.8 | 0.324 |
| Underweight (WAZ<-2) | | 253 | 19.8 | 178 | 25.3 | 0.174 | 101 | 18.8 | 0.838 | 296 | 18.6 | 191 | 17.8 | 0.828 | 41 | 31.7† | 0.050 |
| Wasted (WHZ<-2) | | 253 | 8.3 | 165 | 13.3† | 0.098 | 95 | 6.3 | 0.538 | 296 | 9.5 | 187 | 9.6 | 0.952 | 40 | 7.5 | 0.688 |
| Malaria positive | | 253 | 11.1 | 2 | 0 | 0.618 | 57 | 12.3 | 0.794 | 296 | 8.1 | 2 | 0 | 0.675 | 31 | 12.9 | 0.364 |
| Illness in last 2 days | | 253 | 12.3 | 185 | 9.2 | 0.311 | 106 | 6.6 | 0.112 | 296 | 12.5 | 189 | 6.9† | 0.047 | 39 | 7.7† | 0.384 |

[1] P-value associated with chi-square test for difference in proportion between study and all excluded children 24-59 mo.

[2] P-value associated with chi-square test for difference in proportion between study and excluded children 24-59 mo with Hb measurements.

† No evidence for association with study/excluded status when adjusted for child's age.

n/a = No data available for this indicator and group of children at this time point.

Table 5.7: Characteristics of study and excluded children 24-59 mo by survey year, Malawi

| Characteristic | | 2000 | | | | | | | | 2004 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | |
| | | N | % | N | % | p-value[1] | N | % | p-value[2] | N | % | N | % | p-value[1] | N | % | p-value[2] |
| **Child characteristics** | | | | | | | | | | | | | | | | | |
| Anaemia, | Mild | 466 | 21.5 | | n/a | | 245 | 22.8 | 0.915 | 679 | 25.5 | | n/a | | 187 | 23.5 | 0.941 |
| | Moderate | | 38.8 | | | | | 37.5 | | | 30.2 | | | | | 32.1 | |
| | Severe | | 2.8 | | | | | 3.6 | | | 2.2 | | | | | 2.1 | |
| Age group | 24-35 mo | 466 | 50.9 | 252 | 14.7 | <0.001 | 245 | 40.8 | 0.021 | 679 | 39.8 | 375 | 19.2 | <0.001 | 187 | 39.6 | 0.188 |
| | 36-47 mo | | 32.2 | | 44.8 | | | 35.5 | | | 35.8 | | 36.5 | | | 29.9 | |
| | 48-59 mo | | 17.0 | | 40.5 | | | 23.7 | | | 24.4 | | 44.3 | | | 30.5 | |
| Male | | 466 | 50.0 | 252 | 48.0 | 0.612 | 245 | 47.3 | 0.501 | 679 | 49.9 | 375 | 49.3 | 0.854 | 187 | 57.8 | 0.058 |
| Stunted (HAZ<-2) | | 466 | 57.7 | 214 | 56.5 | 0.772 | 201 | 56.2 | 0.718 | 679 | 55.4 | 323 | 54.2† | 0.722 | 132 | 49.2 | 0.196 |
| Underweight (WAZ<-2) | | 466 | 26.8 | 225 | 23.6 | 0.357 | 227 | 33.0‡ | 0.090 | 679 | 7.7 | 323 | 5.6† | 0.226 | 136 | 6.6 | 0.674 |
| Wasted (WHZ<-2) | | 466 | 7.9 | 221 | 7.2 | 0.748 | 206 | 4.4 | 0.091 | 679 | 0.6 | 322 | 0 | 0.168 | 133 | 0.8 | 0.826 |
| Malaria positive | | 466 | 31.8 | | n/a | | 245 | 43.7‡ | 0.002 | 679 | 13.4 | 12 | 0 | 0.174 | 175 | 13.1 | 0.928 |
| Illness in last 2 days | | 466 | 29.8 | 229 | 19.2‡ | 0.003 | 229 | 23.6‡ | 0.084 | 679 | 19.0 | 356 | 11.8† | 0.003 | 142 | 14.1 | 0.167 |

[1] P-value associated with chi-square test for difference in proportion between study and excluded children 24-59 mo with no Hb measurement (independent sample).

[2] P-value associated with chi-square test for difference in proportion between study and excluded children 24-59 mo with Hb measurements (independent sample).

† No evidence for association with study/excluded status when adjusted for child age.

‡ Evidence for association with study/excluded status, even when adjusted for child age.

n/a = No data available for this indicator and group of children at this time point.

Table 5.8: Characteristics of study and excluded children 24-59 mo by survey year, Tanzania

| Characteristic | | 2000 | | | | | | | | 2004 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | |
| | | N | % | N | % | p-value[1] | N | % | p-value[2] | N | % | N | % | p-value[1] | N | % | p-value[2] |
| Anaemia, | Mild | 634 | 22.6 | n/a | | | 184 | 19.6 | 0.087 | 77 | 22.1 | n/a | | | 169 | 29.6 | 0.111 |
| | Moderate | | 49.2 | | | | | 42.4 | | | 41.6 | | | | | 39.6 | |
| | Severe | | 5.7 | | | | | 7.1 | | | 0 | | | | | 4.1 | |
| Age group | 24-35 mo | 634 | 33.6 | 45 | 31.1 | 0.747 | 184 | 20.7 | <0.001 | 77 | 42.9 | 584 | 31.0 | 0.075 | 169 | 38.5 | 0.307 |
| | 36-47 mo | | 36.3 | | 33.3 | | | 31.0 | | | 28.6 | | 39.7 | | | 38.5 | |
| | 48-59 mo | | 30.1 | | 35.6 | | | 48.4 | | | 28.6 | | 29.3 | | | 23.1 | |
| Male | | 634 | 50.2 | 45 | 57.8 | 0.313 | 184 | 53.3 | 0.459 | 77 | 51.9 | 584 | 44.3 | 0.208 | 169 | 52.7 | 0.917 |
| Stunted (HAZ<-2) | | 634 | 65.3 | 2 | 50.0 | 0.650 | 90 | 62.2 | 0.567 | 77 | 53.2 | 375 | 38.9‡ | 0.020 | 145 | 41.4 | 0.091 |
| Underweight (WAZ<-2) | | 634 | 20.8 | 2 | 0 | 0.469 | 183 | 13.1‡* | 0.019 | 77 | 31.2 | 375 | 22.4 | 0.100 | 146 | 19.2‡ | 0.044 |
| Wasted (WHZ<-2) | | 634 | 1.9 | 2 | 0 | 0.844 | 90 | 2.0 | 0.931 | 77 | 9.1 | 375 | 10.9 | 0.633 | 146 | 9.6 | 0.904 |
| Malaria positive | | 634 | 10.7 | | n/a | | 183 | 7.7 | 0.223 | 77 | 18.2 | | n/a | | 19 | 15.8 | 0.807 |
| Illness in last 2 days | | 634 | 54.1 | 44 | 56.8 | 0.726 | 176 | 52.8 | 0.795 | 77 | 33.8 | 619 | 32.1 | 0.775 | 163 | 32.5 | 0.847 |

[1] P-value associated with chi-square test for difference in proportion between study and all excluded children 24-59 mo.

[2] P-value associated with chi-square test for difference in proportion between study and excluded children 24-59 mo with Hb measurements.

‡ Evidence for association with study/excluded status, even when adjusted for child age.

* When restricted to children with both weight and height data (n=90), underweight prevalence is similar in study and excluded children.

n/a = No data available for this indicator and group of children at this time point.

In terms of the prevalence of anaemia, there was no difference between study and excluded children 24-59 mo with haemoglobin measurements for all countries and years. However, the age distribution of the study sample tended to include more children in the younger age range in at least one time point of all three countries. In Malawi, this bias in sampling occurred during field selection of the sub-sample for haemoglobin measurement and the youngest child between 6 and 59 mo of age in the household was normally selected. In Tanzania, the bias in age distribution was due in large part to a disproportionate number of children 48-59 mo with no height measurement (a study selection criterion) compared to younger children (76% of excluded children 48-59 mo had no height measurement vs. 18% and 33% for children 24-35 and 36-47 mo, respectively). Therefore analysis of the comparability of study and excluded children was adjusted for the child's age when looking at measures of anthropometric status and morbidity.

In Ghana, although the study sample included a larger proportion of younger children in both 2000 and 2004, these children were very similar with respect to nutritional status, morbidity and most household-level characteristics to excluded children. In 2000, children not measured for haemoglobin were somewhat less likely to be fully immunized and more likely to have a mother with no formal education, a farmer as household head and grass roofing material. Children with haemoglobin measurements but incomplete data for other key variables were similar to study children in most respects but also were less likely to be fully immunized or own a radio and more likely to have a mother with no formal education and grass roofing material. In 2004, children without haemoglobin measurements were very similar to the study children but tended to have a slightly lower prevalence of recent illness (6.9% vs. 12.5%, $p=0.07$ when adjusted for child age in months) and were more likely to have a female head of household (27.9% vs. 18.4%, $p=0.014$). There was a very small sample of children with haemoglobin measurements but incomplete data in 2004 ($n=41$). These children were similar to study children in most respects but appeared to be slightly worse off for a few indicators (higher prevalence of underweight, female household heads and collected wood as fuel source).

As noted above, the survey sampling procedure for Malawi haemoglobin measurements resulted in a higher proportion of younger children with haemoglobin data. Thus, in both 2000 and 2004, the sample of children 24-59 with no haemoglobin data has a higher proportion of children in the older age range. In 2000, with the exception of a lower prevalence of recent illness compared to study children (19.2% vs. 29.8%, p=0.003), children with no haemoglobin data were very similar to study children. In 2004, this sample of excluded children also had a lower prevalence of illness in the last two days but this association was attenuated when adjusted for the child's age. However, children without haemoglobin data in 2004 also had slightly lower proportions of farmer and female heads of household and higher proportions of houses with grass roofs, located over five km from the nearest health facility and located in the southern region of the country. The sample of children with haemoglobin but other missing data in 2000 tended to be slightly more underweight and had higher levels of malaria parasitaemia (43.7% vs. 31.8%, p=0.002) compared to study kids, even when adjusted for child age. These children also tended to live closer to a health facility and had a higher proportion of children from the northern region of the country. In 2004, children with haemoglobin but missing data were very similar to study children in most respects, except that they had a lower proportion of children fully immunized (88.3% vs. 97.8%, p<0.001).

In Tanzania, children from the 2000 dataset with no haemoglobin measurement were very similar in characteristics to study children, with the exception of lower levels of children fully immunized and somewhat lower proportion of households with grass roofing. Children who had haemoglobin data but were missing other data in 2000 tended to be older (due to missing height data in most cases). In addition, fewer of these children were underweight[18], had farmer heads of household and had grass roofs, while more were from households with bednets and located further from the nearest health facility, compared to study children. In 2004, the large number of children with no haemoglobin data tended to be older and have better nutritional status (even when adjusted for age) but were less likely than study children to come from a household that

[18] If the analysis was restricted to children with both weight and height data, there was no difference in underweight prevalence between study and excluded children.

owned a bednet. The children in 2004 with haemoglobin data but missing other data (most missing malaria parasitaemia data) also tended to have better nutritional status but were very similar to study children in all other respects.

## 5.3 Variables

Given the nature of the present study (i.e. *post-hoc* analysis of data already collected), the selection of variables of interest was in large part determined by the data available. The following section describes the dependent and independent variables used in the analysis. Where the quality of the data available was a concern, effort was made to understand the reasons for missing data and make careful decisions whether or not to include the variable in question.

### 5.3.1 Primary outcome of interest

Anaemia was the primary outcome of interest in this study, given its utility as a categorical variable for assessing population level changes and translating results into recommendations for program design and targeting. Anaemia was analyzed as a three-level ordinal dependent variable, classified based on haemoglobin concentration cut-offs recommended by the WHO (2001). Children with a haemoglobin concentration ≥ 110 g/L were classified as non-anaemic and children with an haemoglobin concentration between 100 and 109 g/L were classified as mildly anaemic. Due to the fact that very few children had severe anaemia (Hb <70 g/L), all children with Hb <100 g/L were combined to form a single "moderate/severe" anaemia group. Prior to classification, haemoglobin concentration was adjusted for altitude among children living in communities located over 1000 metres above sea level (Nestel, 2002)[19].

### 5.3.2 Independent variables

The analysis examined the association with anaemia of three groups of independent variables – immediate, underlying and basic causes of anaemia – based on the theoretical framework previously described. In addition, the child's age and sex were

[19] Information on altitude was only available for Malawi clusters. Out of 1180 children across both surveys, 36% were adjusted downward by 1 g/L and 22% by 4 g/L. This varied significantly between 2000 and 2004, due to the different distribution of clusters surveyed across the three regions.

included in all analyses, as potential confounders of these relationships. Each group of variables is explained in more detail below. The list of all variable names, their description and coding values are included in Appendix F.

#### 5.3.2.1 Measures of immediate causes of anaemia

The child's nutritional status was defined by calculating height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ) z-scores using WHO Anthro software (WHO, 2007b). The WHO Growth Standards are the current internationally recommended reference for children U5 (WHO Multicentre Growth Reference Study Group, 2006). Children were classified as stunted, underweight and wasted when HAZ, WAZ and WHZ scores were below -2 SD, respectively.

To measure child morbidity, malaria parasitaemia was coded as a binary variable for positive and negative test results and the child's reported illness in the previous two days was also coded as a yes/no variable. Type of illness was inconsistently reported and therefore not used in this analysis.

#### 5.3.2.2 Measures of underlying causes of anaemia

The second group of variables included those factors that represent underlying causes of anaemia and on which the MICAH program intervened directly. Various measures of the household's health and nutrition practices were analyzed. Each child's immunization status was coded as a binary variable, with children who had received all the recommended vaccines (BCG, DPT3, OPV3 and measles[20]) classified as "fully immunized". A child was designated as having received the BCG vaccine if they had either or both a BCG scar and a date recorded in their health card for this vaccine, whether or not they had received the vaccine before the recommended age of 12 months.

Iron supplementation status of children was collected in different ways across the three countries. In Ghana, the variable measured whether the child's primary caregiver reported collecting iron supplements for their children U5, with no specification of

[20] The six target diseases and corresponding vaccines are poliomyelitis (three doses of Oral Polio Vaccine, OPV); Diphtheria Tetanus and Pertussis (three doses, DTP); tuberculosis (Bacille Calmette-Guerin vaccine, BCG); and measles.

which child(ren) received iron supplements. In Malawi, the variable was only collected in 2004 and measured whether the child's primary caregiver reported that their child 6-59 mo received iron supplements every week, with no specification of which child(ren) received them. In Tanzania, the variable was only collected in 2004 and measured whether each specific child under 5 y of age received iron supplements regularly.

Vitamin A supplementation of children was also measured at the household level in Ghana and Tanzania. This variable was coded as positive if the mother reported that the youngest child in the household had received a vitamin A supplement and if the most recent one was received within the last six months.

The mother's reported ANC attendance and visits to a traditional birth attendant (TBA) during her most recent pregnancy were also included. Due to lack of variability (ANC attendance was reported by over 96% of women in all countries), this variable was not utilized in the regression models. The proportion of women who visited a TBA was analyzed for Ghana and Malawi but was not available in Tanzania, since this question was only asked to women there who did not attend ANC.

Due to the importance of dietary factors in the aetiology of anaemia, data on the child's dietary intake were of great interest. However, very little detailed information was collected and each country collected dietary information using different methods. In Ghana and Tanzania, the child's frequency of consuming vitamin A-rich foods and frequency of consuming meat and/or liver in the last seven days was collected in both 2000 and 2004 using an adapted version of the Helen Keller International (HKI) Food Frequency method to assess community risk of vitamin A deficiency (Rosen *et al.*, 1993). In Ghana the questionnaire asked about the frequency with which both meat and liver were consumed by the child in the last seven days but the questionnaire in Tanzania only asked about the child's liver intake. For these data sets, a binary variable was created, coded as 1 for children who had consumed meat and/or liver at least once in the last seven days and 0 for children who had not consumed meat and/or liver. In Malawi, the program did not focus on addressing vitamin A deficiency specifically and therefore the HKI food frequency module was not included in either survey. However, data on the youngest child's dietary intake were collected in 2004 and consisted of a 24-

hour recall of food groups consumed. For the purposes of this study, a binary variable was created, coded as one for children who had consumed meat, fish, poultry, bush meat or rodents in the past 24 hours.

The surveys assessed whether households were raising animals and how the products of those animals were used. Since the program actively promoted the production of *small* animals, the type of animal raised was initially included as a relevant factor. However, preliminary analysis of type of animal raised and consumed showed that households owning small (chicken, rabbit, guinea fowl, duck or pigeon) vs. large (goat, sheep, pig or cow) animals did not differ very much in characteristics or outcomes. Therefore, with the purpose of assessing whether households had access to their own production of meat, a binary variable was created that was coded as one for households that reported "mainly consuming" the meat of at least one type of animal that they owned.

Households reported their main source of water in the wet and dry seasons. Sources that were deemed "potable" were those that were protected in some way from contaminants and included protected wells or springs, boreholes and piped water. Non-potable sources included open surface sources (e.g. river, lake or pond), unprotected wells or springs and roof catchment.

The type of toilet used by the household was assessed based on a question asking where the respondent disposed of excreta. Possible responses included bush or open field, communal or shared latrine, ventilated improved pit latrine, private toilet and flush toilet. Preliminary analysis indicated that in some contexts, outcomes varied not only between use of no toilet vs. any toilet but also between use of a communal/shared vs. a private/improved toilet. Therefore, a three-level variable for toilet type was used, differentiating between those households that used no toilet (bush/open field), a shared/communal toilet and a private/improved toilet.

Household mosquito net utilization was assessed in a variety of ways across countries and between surveys. Therefore, the most common denominator, household ownership of a net (whether insecticide-treated or not), was used for comparison across countries. This measure was not available for Ghana and Malawi in 2000.

#### 5.3.2.3 Measures of basic causes of anaemia

The third group of variables included measures related to the basic causes of anaemia, with an emphasis on maternal and other household-level characteristics.

Maternal age in years was coded as a two-level variable using 30 y as the cut-off point for younger vs. older mothers. Maternal education level was transformed into a two-level variable due to the low number of women with secondary school or higher level of education. Women with no formal education or some informal education (e.g. church, Koran, literacy) were differentiated from those with some primary or higher level schooling. The education level of the household head was created in a similar manner. Given the predominance of farming as a livelihood for the majority of households, the household head's work status was coded as a two-level variable, with one level for farmers and the other level for those with other occupations (e.g. regular wage earner, business/trade, pensioner, etc.). Household head work status was not available for Ghana in 2004.

##### *5.3.2.3.1 Wealth index*

The effect of household socioeconomic status on child health and nutritional status is well-documented (Haddad *et al.*, 2003; Fotso & Kuate-Defo, 2006). Given the difficulty in measuring household income or consumption expenditure due to recall bias, seasonality and data collection burden, asset-based measures are often used as a proxy for longer-term household economic status (Vyas & Kumaranayake, 2006). Following collection of asset variables at the household level, the data are often aggregated in some way, as most individual asset variables are not sufficient to differentiate household socioeconomic status (Vyas & Kumaranayake, 2006). Filmer and Pritchett (2001) propose that the use of principal components analysis is pragmatic, avoiding the problems associated with using equal weights for all variables in the index or attempting to estimate the price or value of each asset. However, principal components analysis was designed for use with continuous, normally-distributed variables and therefore its application to the categorical variables in a wealth index is considered by some to be inappropriate (Booysen *et al.*, 2008; Howe *et al.*, 2008). Multiple correspondence analysis is analogous to principal components analysis but is designed for use with

discrete data. Based on work by Howe et al. (2008), comparison of indices generated by principal components and multiple correspondence showed a high level of agreement. Therefore, multiple correspondence analysis was used to create a wealth index for the purposes of this analysis.

The first step was to select the variables to be included in the index. The MICAH surveys collected a variety of information related to the household's socioeconomic status, including ownership of durable assets (e.g. radio, bicycle, table and chair), housing characteristics (e.g. roofing material, fuel source and number of rooms) and access to sanitation facilities and source of water. Data on maternal and household head occupation and education were also collected in most surveys. Given the explanatory nature of the analysis, it was deemed preferable to create an asset index that did not include direct determinants of child health and survival (Houweling *et al.*, 2003). For example, water sources, type of toilet used and animal ownership are believed to be related to a child's risk of anaemia, the outcome of interest. Therefore, only household durable assets and housing characteristics were included. Household index scores created using these two groups of variables were observed to produce a reasonable distribution (limited clumping and truncation). Table 5.9 presents a summary of the specific items used to create the wealth index in each country.

Table 5.9: List of questions used to derive wealth index in each country

| **Core variables in wealth index** | **Ghana** | **Malawi** | **Tanzania** |
|---|---|---|---|
| Household has: radio, bicycle, mattress, chair, table | ✓plus television, tape recorder, lamp | ✓ plus television, tape recorder, paraffin lamp | ✓ plus "improved" lamp (paraffin or hurricane) |
| Household has electricity | ✓ | – | – |
| Roofing material | ✓ | ✓ | ✓ |
| Main type of cooking fuel used | ✓ | ✓ | ✓ |
| Number of people in household per room | – | ✓ | ✓ |

To assign a loading to each variable and calculate the wealth index score, multiple correspondence analysis was applied to each country's data set by survey year separately. The PRINCALS command in SPSS 15.0 was used; it does not assume the

relationships among observed variables to be linear. Initially the first two dimensions were examined. However, the first dimension performed in a manner consistent with what one would expect in terms of distinguishing between assets or household characteristics typical of rich vs. poor households. Therefore, only the component loadings from the first dimension were used to create a composite index score for each household.

Households within each survey year and each country were divided into quintiles based on their index score. Due to sample size limitations, the second, third and fourth quintiles were combined to form the middle 60% of relative wealth ranking. In this way, the three-level ranking compares the relatively poorest 20% of households with the middle majority (60%) and the relatively richest 20%.

In order to determine whether the resulting index was performing according to expectations, several tests for internal coherence were conducted. The mean value for each asset variable included in the country's index was compared across the three ranking levels, in order to determine if ownership of assets increased with wealth index ranking. In addition, the association between wealth index ranking and characteristics of the child and the household were examined. See Appendix G for the summary of this analysis in each country. Overall, the results showed strong internal coherence. Mean values for ownership of assets, improved roofing material, access to electricity and use of improved cooking fuels increased across wealth groups in all datasets. The proportion of mothers and household heads with no education was highest among the poorest and lowest among the least poor households. Child stunting prevalence also showed a consistent decrease across wealth groups, as shown in other studies (Wagstaff & Watanabe, 2003; Hong, 2007; Wamani *et al.*, 2007). Therefore, the wealth index was included in the remainder of the analysis.

Distance to the nearest health facility was collected in different ways across time and countries and therefore coded according to the underlying unit of data available. Proximity was coded as "within village" if the nearest health facility was within a 15 minute walk from the household. An intermediate distance was defined as "within 5 km" and this included distances that were estimated as within a two hour walk from the

household. The furthest distance, “over 5 km”, included any estimates of over two hours walking from the household or community.

Other identifying variables were available, such as the community, implementing partner (Malawi only), World Vision Area Development Programme (ADP), or administrative unit (e.g. region, division, subdistrict). However, since none of these were consistent across time and country, they were only used in country-specific analyses where relevant.

#### 5.3.2.4 Measures of child age and sex

The child’s age was calculated in months using the date of the household interview and the child’s date of birth as recorded on the child’s health card, or as reported by the primary caregiver if the health card was not available. The proportion of children with a date of birth recorded in their health card varied by country, with Ghana having the highest proportion (82% in 2000 and 86% in 2004). In Malawi, 66% and 61% of children had this information in 2000 and 2004, respectively. Only 54% had this information recorded in 2000 in Tanzania but this increased to 66% in 2004. Some evidence of age heaping was found among ages reported by caregiver, with preference for 24, 36 and 48 months. Verification of the child’s age was done using data on BCG vaccination date, wherever possible. Finally, an age group variable was created to allow for analysis of differences between children 24-35, 36-47 and 48-59 mo. Child’s sex was coded based on the data from the immunization record questionnaire.

## 5.4 Statistical analysis

Statistical analysis was performed using SPSS version 16.0 (SPSS, Inc., Chicago IL) and Stata version 9.2 (StataCorp LP, College Station, TX). Statistical significance was defined as a p-value of $<0.05$. Although the data were originally collected using a two-stage cluster sampling design, due to the fact that the current analysis is not seeking to make estimates that are representative of any national or other administrative area population, the data are considered to be adequately self-weighted and no design weights were used in the analysis.

### 5.4.1 Descriptive analysis

The data were initially described and summarized using univariate statistics to document the distribution of child and household characteristics in 2000 and 2004 for each country. Based on evidence of slightly different distributions by age group and sex across time and countries, the prevalence of mild and moderate/severe anaemia was standardized by child age (in 6-mo groupings) and sex using the pooled sample as the standard population (Kahn, 1983) to allow for direct comparisons at the descriptive level. For standardized values, 95% Wald confidence intervals for difference in proportions were calculated (Agresti, 2007). Differences in the distribution of each variable between 2000 and 2004 in each country were assessed using the chi-square test.

Mean haemoglobin levels and mean z-scores for anthropometric indices were estimated by year and country, along with their respective standard deviations. Differences in means between 2000 and 2004 were compared by Student's t-test.

### 5.4.2 Risk factor analysis

The relationship between potential risk factors for anaemia and anaemia status was examined first at the univariate level, separately for each year and country. All key variables expected to be associated with anaemia status were coded as categorical variables (as explained above) and assessed for their association with anaemia status (none, mild or moderate/severe anaemia) using cross-tabulation. A chi-square test was performed to test the null hypothesis of no association between each risk factor and anaemia status.

Multivariate analysis of risk factors for mild and moderate/severe anaemia was carried out using polynomial logistic regression models built separately for each country but using the combined dataset for survey years 2000 and 2004. The dependent variable represented anaemia status with three levels: 0=no anaemia, 1=mild anaemia and 2=moderate/severe anaemia. A series of models were built using blocks of independent variables (see Table 5.10) that were consistent with the conceptual model presented in Figure 4.1. Only those variables that were available at all time points and across the three countries were included.

Table 5.10: Description of blocks of variables used in the multivariate analysis of anaemia risk factors

| **Block description** | **Specific variables included in block** |
|---|---|
| Immediate causes of anaemia[1] | • Child stunting status (1=stunted, 2=non-stunted)<br>• Child malaria parasitaemia (1=positive, 2=negative)<br>• Child illness in the past two days (1=yes, 2=no) |
| Underlying causes of anaemia[2] | • Household use of potable water source (0=no, 1=yes)<br>• Household toilet type used (0=bush/ground, 1=shared/communal, 2=private/improved) |
| Basic causes of anaemia[3] | • Mother's education level (0=none/non-formal, 1=primary or above)<br>• Wealth index rank (1=lowest 20%, 2=middle 60%, 3=highest 20%)<br>• Distance to nearest health facility (1=over 5km, 2=within 5km, 3=in community) |
| Potential confounding variables | • Child age group (1=48-59 mo, 2=36-47 mo, 3=24-35 mo)<br>• Child sex (0=female, 1=male) |

[1] Underweight and wasted status not included due to high colinearity with stunting.

[2] ANC attendance not included due to insufficient variability (all countries >96%). Animal source food production and consumption, iron supplement access, vitamin A supplement status and mosquito net ownership not included due to missing data for one or more country data sets. Child immunization status not included due to general lack of evidence for association with anaemia in preliminary analysis and desire to minimize number of variables included in the multivariate model.

[3] Household head work type and maternal nutrition knowledge not included due to missing data for one or more country data sets. Household head education level and mother's age group not included due to general lack of evidence for association with anaemia in preliminary analysis and desire to minimize number of variables included in the multivariate model.

Model 1 estimated the effect of the immediate determinants of child anaemia (stunting, malaria, recent illness), adjusted for survey year. Model 2 estimated the effect of these immediate determinants, adjusted for the confounding role of underlying causes on which the program was expected to have an effect, as well as any residual effect of these underlying causes that is not mediated through the immediate causes. Model 3 estimated the effect of immediate causes, adjusted for underlying and basic causes of anaemia, the effect of underlying causes that is not mediated through the immediate causes, and the effect of basic causes that is not mediated through underlying or

immediate causes. Model 3 also included child age group and sex as potential confounders of these relationships.

Since the prevalence of anaemia exceeds 10 percent in each dataset, the adjusted odds ratios are likely overestimates of the relative risk. Various statistical approaches have been proposed for estimating an adjusted relative risk and its confidence interval when the incidence of disease is common and confounding exists (Zhang & Yu, 1998; McNutt *et al.*, 2003; Greenland, 2004). Although the log-binomial and Poisson regression models have been proposed as useful approaches to obtaining unbiased estimates of the adjusted relative risk in studies with common outcomes, these models are not suitable for a three-level dependent variable. Routine programs for such a variable (e.g. log-multinomial regression) are not yet commonly available. Therefore, the Zhang and Yu method (1998) was used to correct the adjusted odds ratios, recognizing that the resulting risk ratio may sometimes be biased away from the null, suggesting a stronger association than is true, and the corrected confidence intervals may also be more narrow (McNutt *et al.*, 2003).

The following formula was applied to the adjusted odds ratios (OR) derived from the multinomial logistic regression models applied to each country dataset:

$$RR = \frac{OR}{(1 - P_0) + (P_0 \times OR)}$$

where $P_0$ is the incidence of anaemia in the non-exposed group, OR is the adjusted odds ratio and RR is the corrected risk ratio (Zhang & Yu, 1998). As expected, comparison of the original adjusted OR and the corrected RR estimates showed a reduction in the magnitude of the associations.

To test the hypothesis of changes between 2000 and 2004 in the risk relationships between mild and moderate/severe anaemia and immediate causes (stunting, malaria and recent illness), the plan for analysis was to use two-way interaction terms with survey year for each of these risk factors in the multinomial logistic regression model. Interaction terms with regression coefficients significant at the level of $p<0.15$ would provide evidence that the risk estimate was different in 2000 compared to 2004. However, the datasets were insufficiently powered for this type of

analysis. Although some interaction terms were significant, the confidence limits for the corresponding odds ratios by year were overlapping and interpretation of these results was problematic.

To explore possible alternatives, moderate/severe anaemia was modeled as a binomial outcome (e.g. Hb <100 g/L) using different distributions (log-binomial, log-log, clog) but estimates of model fit were a concern and little evidence was found for significant interaction terms. Therefore, this aspect of the research objectives was explored further using haemoglobin as a continuous variable in linear regression models.

### 5.4.3 Multiple linear regression models

There are two main benefits to modeling haemoglobin as a continuous dependent variable: 1) it provides added statistical power and 2) estimates of the magnitude of association with mean haemoglobin for risk factors are directly comparable with existing literature on the subject, since no consensus is needed on a cutoff point. To maximize the statistical power of the analysis, data were combined for all countries and years. One-way analysis of variance (ANOVA) was used to examine the association with mean haemoglobin by year of all risk factors included in the logistic regression models; an F-test with a probability value of <0.05 was considered evidence of a significant association.

Multiple linear regression models were built in a similar manner to the logistic regression models, adding with each model another block of independent variables that were consistent with the conceptual model. In order to adjust for the variance associated with country and year, these variables were included in all models. Child age group and sex were also included in all models as potential confounders of the association of all risk factors with haemoglobin levels.

To test for variation between years in the observed associations, two-way interaction terms were included in the final pooled model (Model 4) for survey year with the three variables considered as immediate causes of anaemia (stunting, malaria, illness) as well as year with country. Interaction terms significant at $p<0.15$ were

considered as evidence for variation between 2000 and 2004 in the association of the risk factor with mean haemoglobin.

When little evidence for variation by year was found in the pooled model, country-specific models were run using the full set of variables and including interaction terms for survey year with stunting, malaria and illness. For the two risk factors with evidence of variation by year (malaria and recent illness), marginal means were estimated in each country model to compare mean haemoglobin levels by year and risk factor. Marginal means are the model-estimated means, not the observed means, by level/category of the risk factor.

### 5.4.4 Comparison of differences by sub-group

To assess whether the differences observed in anaemia prevalence between years were similar for sub-groups of children with specific nutrition and health characteristics, a comparison was made of the difference in predicted prevalence of mild and moderate/severe anaemia between 2000 and 2004 in each country and sub-group. In order to adjust for confounding, the predicted prevalence of anaemia severity was estimated using a multinomial logistic regression model fitted for each country and year. The predicted prevalence is the estimated probability of mild and moderate/severe anaemia for a specified value of each independent variable of interest (e.g. stunted, non-stunted, malaria positive, malaria negative, recently ill or not recently ill), holding all other variables in the model at their mean. Consistent with previous models in this study, each model included the variables age group, sex, stunting, malaria, recent illness, potable water, latrine type, wealth ranking, maternal education level and distance to health facility. Following estimation of the model (*mlogit* in Stata) for each country and year combination, the post-estimation command *prvalue* was used to estimate the predicted prevalence. For each health/nutrition status sub-group, the difference in predicted prevalence of mild and moderate/severe anaemia between 2000 and 2004 was calculated along with the 95% confidence interval for the difference.

### 5.4.5 Population attributable risk

To assess the public health significance of undernutrition and morbidity on the prevalence of anaemia, population attributable risk (PAR) estimates were calculated. PAR is defined as the risk in the total population minus the risk in the unexposed group, in other words, the "excess" risk attributable to the risk factor. For example, it answers the question: "Among children 24-59 mo, what percentage of the total risk for anaemia is associated with stunting?" Since the analysis is best suited to situations with a binary outcome variable (disease-no disease), the PAR calculation is limited in this study to the risk of moderate/severe anaemia (Hb <100 g/L). Furthermore, the analysis will focus on the excess risk attributable to stunting, malaria and recent illness.

Given the expected confounding of the association between anaemia and its immediate risk factors (stunting, malaria and recent illness), the following formula was used which is expected to produce an internally valid estimate when used with adjusted relative risks (Rockhill et al., 1998).

$$PAR\% = pd\left(\frac{RR-1}{RR}\right)\times 100$$

(RR=adjusted relative risks; *pd* = proportion of cases exposed to risk factor)

Adjusted relative risks for binary outcomes can be estimated with a log-binomial or Poisson regression model (Lindquist, n.d.). Although we tried building a log-binomial regression model for this study, we experienced the convergence problems noted in the literature (McNutt *et al.*, 2003). Therefore, the RR for stunting, malaria and recent illness were estimated using a Poisson regression model with a robust error variance for each country and year. Each model adjusted the risk estimates for all other variables included in the previous regression models (age group, sex, stunting, malaria, recent illness, potable water, latrine type, wealth ranking, maternal education level and distance to health facility).

## 5.5 Summary

The results of the analyses outlined above, including consideration of the specificity of each geographical area and of changes in relative risk and prevalence of risk factors, will be discussed from a public health perspective in terms of the evolution of anaemia in the context of an integrated program designed to reduce it and the changes in the risk factors for anaemia following such an effort. Similarities and differences across country contexts will be examined along with consideration of the limitations of the study. Finally, implications for future anaemia control efforts will be explored.

# CHAPTER 6: RESULTS

# 6 Results

The results start with a description of the characteristics of the samples of children 24-59 mo living in communities that benefitted from the MICAH program interventions in Ghana, Malawi and Tanzania. The differences observed between 2000 and 2004 in anaemia prevalence in these children will be presented, followed by the risk factor analysis. Finally, the results of the analysis of population attributable risk and comparison of relative differences by child health status will be shown.

## 6.1 Description of the study sample

Data from the 2000 and 2004 household surveys in MICAH program areas in Ghana, Malawi and Tanzania were used to describe the health and nutrition status among children 24-59 mo. Data were available for a total of 1,353 children in 2000 and 1,052 children in 2004.

### 6.1.1 Characteristics of study children

Characteristics of the children included in this study are presented in Table 6.1 by country and survey year. The distribution by age group was similar in 2000 and 2004 in Ghana and Tanzania but in Malawi, there were more children in the youngest age group in 2000 than in 2004. A similar proportion of boys and girls was observed in each year of each country.

***Nutritional status*** – Anthropometric indicators of child nutritional status showed that undernutrition was a problem of public health significance in all three countries. In Ghana, the prevalence of stunting (HAZ <-2 SD) was 37.2% in 2000 and 29.1% in 2004 (p=0.04). The mean HAZ was similar at both time points: -1.55 (SD 1.23) and -1.49 (SD 1.33) in 2000 and 2004, respectively (p=0.61). Approximately one fifth of Ghanaian children were considered underweight (WAZ <-2 SD) in both years and the mean WAZ also was similar: -1.11 (SD 1.06) and -1.13 (SD 1.08) in 2000 and 2004, respectively (p=0.90). Less than 10% were wasted (WHZ <-2 SD); the mean WHZ was -0.34 (SD 1.26) in 2000 and -0.40 (SD 1.17) in 2004 (p=0.55).

High levels of undernutrition also were evident in Malawi, with over half of the children showing evidence of stunting in both years and no difference in the mean HAZ between 2000 (-2.22, SD 1.47) and 2004 (-2.24, SD 1.13; p=0.80). The proportion of children underweight was 26.8% in 2000 and was much lower (7.7%) in 2004 (p<0.001). The mean WAZ was also higher in 2004 compared to 2000 (-0.50 vs. -1.39, p<0.001). These differences were associated with a lower prevalence of wasting and higher mean WHZ (1.16 vs. -0.16, p<0.001) in 2004 compared to 2000.

Chronic malnutrition was also highly evident in both samples in Tanzania, but the stunting level was significantly lower in 2004, changing from 65.5% in 2000 to 53.2% in 2004 (p=0.035). Accordingly, the mean HAZ was also higher in 2004 compared to 2000: -1.90 (SD 1.17) vs. -2.44 (SD 1.18; p<0.001). The prevalence of underweight remained similar at each time point, as did the mean WAZ (-1.26 in 2000 and -1.36 in 2004, p=0.39). Consistent with these changes, the wasting level was higher in 2004 (9.1%) compared to 2000 (1.9%) and the mean WHZ was lowered between 2000 and 2004 (0.24 (SD 1.02) to -0.41 (SD 1.24), p<0.001).

***Morbidity*** - Morbidity levels were measured by malaria parasitaemia and recent illness. In Ghana, morbidity was relatively low and constant over time. Malaria parasitaemia was observed in 31.8% of children in 2000 in Malawi but this was lower in 2004 (13.4%, p<0.001). The proportion of children recently ill was also lower in 2004 in Malawi, changing from 29.8% in 2000 to 19.0% in 2004 (p<0.001). In Tanzania, malaria parasitaemia was observed in 10.7% of children in 2000 and 18.2% in 2004 (p=0.05). Recent illness among children was significantly lower in 2004 than in 2000 (33.8% vs. 54.1%, p=0.001).

***Health and nutrition practices*** – In terms of health and nutrition practices reported by mothers of a child U5, almost all women (96-99%) reported having attended ANC during their most recent pregnancy across all countries and time points. In Ghana, access to iron supplements for children was very high, with 91.9% and 82.8% of caregivers in 2000 and 2004, respectively, reporting that they collected the supplements for their child U5. Although not measured in 2000, iron supplementation for children was reported in 2004 by 73.9% of mothers in Malawi and 36.2% of children in Tanzania

received iron supplements regularly. In all three countries, a high proportion of the children were fully immunized in 2000 and this level was even higher in 2004 in Ghana and Malawi, but stayed similar in Tanzania.

Less than half of households in all three countries reported raising at least one type of animal and mainly consuming its products (meat). However, the proportion of children in Ghana who had consumed meat or liver at least once in the past week increased from 56.8% in 2000 to 66.2% in 2004 ($p=0.03$). Child liver consumption in the past week remained low for both years in Tanzania. In Malawi in 2004, 27.2% of children had eaten meat, fish or poultry in the last 24 hours.

Access to potable water sources was similar at both time points in all three countries but the level of access to potable water was much higher in Ghana and Malawi compared to Tanzania. The proportion of households that reported use of private or improved toilets remained relatively stable during the period under study at 38.3 to 40.5% in Ghana, 77.0 to 79.7% in Malawi and 75.6 to 63.6% in Tanzania. Mosquito bed net ownership was significantly higher in Tanzania in 2004 (63.2%) compared to 34.4% in 2000 ($p<0.001$). Bed net ownership is also believed to have increased during this period in Ghana and Malawi, although this indicator was not directly measured in 2000. In Ghana, DHS data from the program region in 1999 showed that 10% of households owned a bed net and MICAH data in 2004 found that 34.8% of households in program areas owned a bed net. In Malawi, 9% of households surveyed in 2000 reported using a mosquito net to prevent malaria and in 2004, actual ownership of mosquito bed nets was 76.1%.

***Household characteristics*** – The proportion of mothers less than 30 years of age was similar in 2000 and 2004 in all three countries. The proportion of mothers with no formal education also remained constant in Ghana and Tanzania but in Malawi, where it was highest, this proportion was lower in 2004 compared to 2000.

The majority (68-93%) of households were headed by male members and most of these reported farming as their primary occupation. Over 84% of households in all surveys reported owning land or having a farm; ownership of animals was also very common and remained stable over time in all three countries.

Table 6.1: Child and household characteristics by country and survey year

| Characteristic | | GHANA | | | | | MALAWI | | | | | TANZANIA | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000 | | 2004 | | p-value[1] | 2000 | | 2004 | | p-value[1] | 2000 | | 2004 | | p-value[1] |
| | | N | % | N | % | | N | % | N | % | | N | % | N | % | |
| **Child characteristics** | | | | | | | | | | | | | | | | |
| Age group | 24-35 mo | 253 | 41.5 | 296 | 39.2 | 0.586 | 466 | 50.9 | 679 | 39.8 | <0.001 | 634 | 33.6 | 77 | 41.6 | 0.348 |
| | 36-47 mo | 253 | 32.4 | 296 | 30.7 | | 466 | 32.2 | | 35.8 | | 634 | 36.3 | | 29.9 | |
| | 48-59 mo | 253 | 26.1 | 296 | 30.1 | | 466 | 17.0 | | 24.4 | | 634 | 30.1 | | 28.6 | |
| Male | | 253 | 51.0 | 296 | 54.4 | 0.426 | 466 | 50.0 | 679 | 51.7 | 0.573 | 634 | 50.2 | 77 | 51.9 | 0.767 |
| Stunted (HAZ<-2) | | 253 | 37.2 | 296 | 29.1 | 0.044 | 466 | 57.7 | 679 | 55.4 | 0.431 | 634 | 65.5 | 77 | 53.2 | 0.035 |
| Underweight (WAZ<-2) | | 253 | 19.8 | 296 | 18.6 | 0.726 | 466 | 26.8 | 679 | 7.7 | <0.001 | 634 | 20.8 | 77 | 31.2 | 0.038 |
| Wasted (WHZ<-2) | | 253 | 8.3 | 296 | 9.5 | 0.635 | 466 | 7.9 | 679 | 0.6 | <0.001 | 634 | 1.9 | 77 | 9.1 | <0.001 |
| Malaria positive | | 253 | 11.1 | 296 | 8.1 | 0.238 | 466 | 31.8 | 679 | 13.4 | <0.001 | 634 | 10.7 | 77 | 18.2 | 0.053 |
| Illness in last 2 days | | 253 | 12.3 | 296 | 12.5 | 0.930 | 466 | 29.8 | 679 | 19.0 | <0.001 | 634 | 54.1 | 77 | 33.8 | 0.001 |
| **Health and nutrition practices** | | | | | | | | | | | | | | | | |
| Fully immunized | | 253 | 77.1 | 296 | 84.5 | 0.028 | 466 | 86.1 | 679 | 97.8 | <0.001 | 634 | 86.4 | 77 | 80.5 | 0.160 |
| Iron supplements[2] | | 248 | 91.9 | 296 | 82.8 | 0.002 | — | — | 609 | 73.9 | — | — | — | 69 | 36.2 | — |
| Mother attended ANC, last pregnancy | | 247 | 96.8 | 296 | 98.6 | 0.136 | 435 | 97.5 | 624 | 98.2 | 0.390 | 630 | 98.4 | 75 | 98.7 | 0.867 |
| Mother saw TBA, last pregnancy | | 244 | 41.4 | 294 | 33.0 | 0.044 | 435 | 7.8 | 624 | 3.4 | 0.001 | — | — | 70 | 62.9 | — |
| Produce & consume ≥1 meat source | | 253 | 49.0 | 296 | 42.6 | 0.131 | — | — | 679 | 38.3 | — | 390 | 45.9 | 44 | 29.5 | 0.038 |
| Child ate meat/liver ≥1 time[3] | | 220 | 56.8 | 293 | 66.2 | 0.030 | — | — | 580 | 27.2 | — | 536 | 14.4 | 68 | 14.7 | 0.940 |

*…continued on next page*

Table 6.1: Child and household characteristics by country and survey year, *continued*

| | GHANA | | | | | MALAWI | | | | | TANZANIA | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Characteristic** | **2000** | | **2004** | | **p-value** | **2000** | | **2004** | | **p-value** | **2000** | | **2004** | | **p-value** |
| | N | % | N | % | | N | % | N | % | | N | % | N | % | |
| Protected water source (dry season) | 253 | 73.9 | 296 | 77.7 | 0.300 | 466 | 85.6 | 679 | 82.9 | 0.220 | 634 | 47.5 | 77 | 42.9 | 0.443 |
| Private, improved toilet use | 253 | 38.3 | 296 | 40.5 | 0.725 | 466 | 77.0 | 679 | 79.7 | 0.003 | 634 | 75.6 | 77 | 63.6 | <0.001 |
| Mosquito bed net owned | — | —[4] | 296 | 34.8 | — | — | —[5] | 675 | 76.1 | — | 630 | 34.4 | 76 | 63.2 | <0.001 |
| **Household characteristics** | | | | | | | | | | | | | | | |
| Number of members, mean | 253 | 5.46 | 296 | 5.10 | 0.031 | 466 | 4.86 | 679 | 5.16 | 0.004 | 634 | 6.23 | 77 | 5.53 | 0.012 |
| Maternal age <30 y | 253 | 47.8 | 295 | 51.2 | 0.433 | 466 | 52.4 | 679 | 56.8 | 0.134 | 634 | 54.4 | 77 | 42.9 | 0.055 |
| Maternal education, none/non-formal | 253 | 11.9 | 296 | 14.9 | 0.304 | 466 | 36.1 | 679 | 23.6 | <0.001 | 634 | 26.3 | 77 | 23.4 | 0.576 |
| Female-headed household | 253 | 24.9 | 296 | 18.2 | 0.058 | 466 | 32.2 | 679 | 15.3 | <0.001 | 634 | 10.3 | 77 | 6.5 | 0.296 |
| Farmer-headed household | 253 | 60.9 | | — | — | 466 | 64.4 | 673 | 71.2 | 0.015 | 634 | 86.6 | 77 | 83.1 | 0.403 |
| Own land or have farm | 251 | 87.6 | 296 | 87.2 | 0.864 | 466 | 98.1 | 673 | 99.3 | 0.130 | 630 | 84.7 | 76 | 84.2 | 0.900 |
| Own animals | 253 | 78.3 | 295 | 77.6 | 0.858 | 466 | 68.9 | 679 | 72.2 | 0.230 | 631 | 60.4 | 77 | 57.1 | 0.584 |
| Own a radio | 253 | 60.9 | 296 | 85.1 | <0.001 | 466 | 51.3 | 679 | 67.5 | <0.001 | 633 | 46.0 | 77 | 55.8 | 0.101 |
| Own a bicycle | 253 | 21.3 | 296 | 28.0 | 0.071 | 466 | 40.8 | 679 | 46.8 | 0.043 | 634 | 44.3 | 77 | 41.6 | 0.645 |
| Reed/grass roof material | 253 | 2.4 | 296 | 8.4 | 0.002 | 466 | 88.6 | 679 | 84.8 | 0.066 | 634 | 70.7 | 77 | 55.8 | 0.008 |
| Collect wood as fuel source | 253 | 81.0 | 296 | 83.8 | 0.397 | 466 | 95.1 | 679 | 96.5 | 0.240 | 633 | 94.6 | 77 | 93.5 | 0.683 |
| Health facility >5km from household[6] | 253 | 33.2 | 296 | 19.6 | <0.001 | 466 | 57.9 | 679 | 25.5 | <0.001 | 634 | 9.9 | 77 | 26.0 | <0.001 |

*…continued on next page*

Table 6.1: Child and household characteristics by country and survey year, *continued*

[1] P-value associated with chi-square test between years within each country

[2] Ghana: Mother reported collecting iron supplements for youngest child in the household; Malawi: Iron supplements received weekly for a child in the household; Tanzania: Specific child received iron supplement regularly.

[3] Ghana: Child ate meat or liver at least once in the preceding 7 days; Malawi: Child ate meat, fish or poultry in last 24 hours; Tanzania: Child ate liver at least once in the preceding 7 days.

[4] Not assessed in survey but assumed to be less than 10%, based on DHS results for the region.

[5] Not assessed in survey but 9% of households reported using mosquito net to prevent malaria.

[6] Ghana: over 5 km from household; Malawi: more than 2 hr walk (2000) or over 5 km (2004); Tanzania: over 5 km (2000) or more than 2 hr walk (2004).

Proxy indicators of household economic status show that ownership of various assets generally was higher in 2004 than in 2000 in the program areas surveyed. The proportion of households owning a radio ranged from 46.0 to 60.9% in 2000 and was higher in 2004 in all three countries. Ownership of a bicycle was a little less common and was higher in 2004 compared to 2000 only in Malawi. One major difference across countries was in the proportion of households using grass roofing material – this was less than 10% in Ghana, ranged from 56-70% in Tanzania and constituted the majority (85-88%) in Malawi. Yet the vast majority of households in all three countries reported collecting wood for their primary cooking fuel source. The proportion of households that reported a distance of over 5 km (or over 2 hours walk) to the nearest health facility was lower in 2004 compared to 2000 in both Ghana and Malawi. However, in Tanzania, this proportion was low in 2000 (9.9%) and much higher in 2004 (26.0%).

### 6.1.2 Prevalence of anaemia

The overall prevalence of anaemia among children 24-59 mo living in the study sampled areas in 2000 ranged from 59.8% in Ghana to 63.0% in Malawi and 77.7% in Tanzania, as shown in Figure 6.1. Severe anaemia accounted for a small proportion of these cases across all three countries and both time points. The majority of cases were considered moderate in severity in all countries and over time.

Overall, anaemia prevalence (Hb <110 g/L) was lower in Ghana in 2004 (59.8%) compared to 2000 (30.5%; difference 29.4%, 95% CI 21.4, 37.4). A lower prevalence was observed in 2004 for both mild and moderate cases. In Malawi, the overall prevalence of anaemia was 63.0% in 2000 and 57.8% in 2004 (difference 5.1%; 95% CI -0.6, 10.9). Only the prevalence of moderate anaemia was significantly lower in 2004 (30.2%; 95% CI 26.8, 33.7) compared to 2000 (38.7%; 95% CI 34.3, 43.2) in this country context. The overall prevalence of anaemia in Tanzania areas was also lower in 2004 compared to 2000 (77.7% in 2000; 65.4% in 2004; difference 12.3%, 95% CI 1.2, 23.4), but the difference in prevalence of mild or moderate anaemia between the two time points was not different from zero.

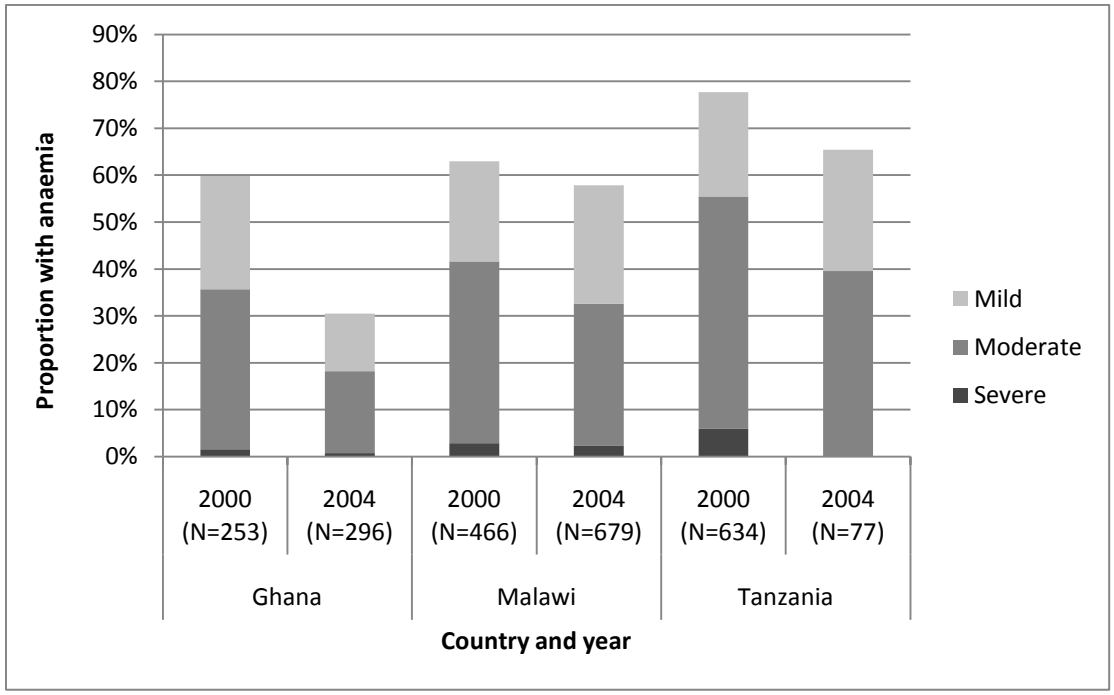



Figure 6.1: Prevalence of anaemia by severity over time and by country[21]

Figure 6.2 shows the difference in mean haemoglobin levels between the two time points in each country, with evidence of a significant shift to the right in the overall haemoglobin distribution between 2000 and 2004 in all three countries. In Ghana, the mean was 8.7 g/L higher (95% CI 6.2, 11.2; $p<0.001$) in 2004, changing from 105.0 g/L (SD 15.8) in 2000 to 113.7 g/L (SD 13.9) in 2004. Malawi mean haemoglobin levels also differed between 2000 (103.1 g/L; SD 17.6) and 2004 (105.9 g/L; SD 16.4), a difference of 2.7 g/L (95% CI 0.8, 4.8; $p=0.008$). The mean haemoglobin was 5.2 g/L (95% CI 1.1, 9.3; $p=0.012$) higher in Tanzania in 2004 (102.1 g/L; SD 15.0) compared to 2000 (96.9 g/L; SD 17.4).

[21] Standardized based on pooled sample distribution by age (6-mon groups) and sex

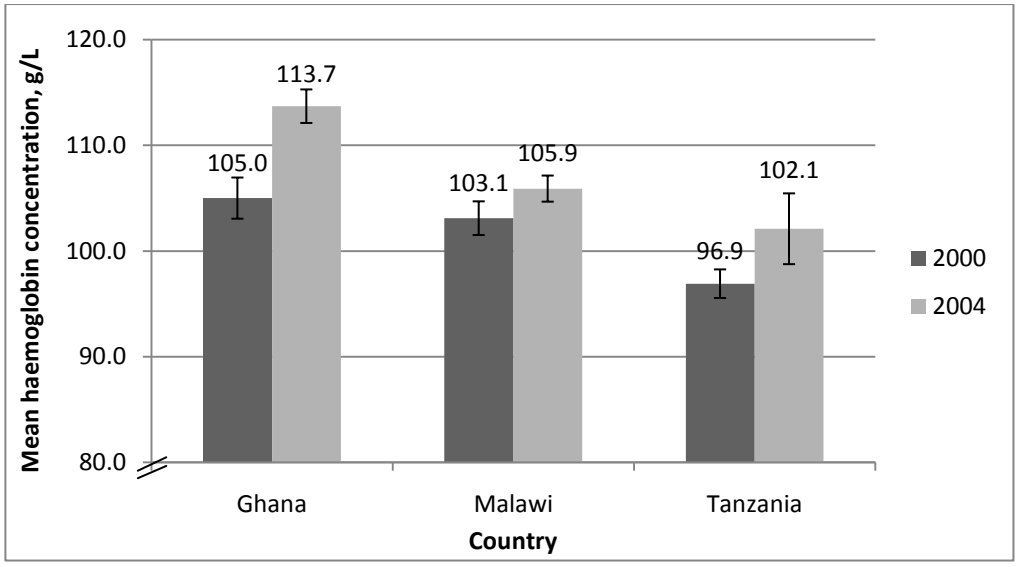



Figure 6.2: Mean haemoglobin by country and survey year (Error bars 95% CI)

## 6.2 Risk factors for anaemia

The following section describes the risk factors associated with anaemia severity in each country using univariate and multivariate analytic methods. The magnitude of association for risk factors with mean haemoglobin is presented, as well as evidence for variation in this association by survey year.

### 6.2.1 Factors associated with anaemia status in univariate analysis

#### 6.2.1.1 Ghana

Table 6.2 shows the results of the univariate analyses for children from Ghana in 2000 and 2004. An association of child nutritional status with anaemia status was evident. Stunting was associated with an increased risk of moderate/severe anaemia ($p<0.05$) but not mild anaemia in both years. In addition, recent illness, household wealth ranking and distance to the nearest health facility were significantly associated with anaemia status in 2000.

There was no evidence for an association with anaemia status for malaria status, immunization status, iron supplement access, water source, type of toilet used, animal

ownership or animal source food production/consumption, maternal age or education level, household head education level or child sex and age group.

Table 6.2: Characteristics of children 24-59 mo by anaemia status, Ghana

| Characteristic | | 2000 (N=253) | | | | 2004 (N=296) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | n | Normal % | Mild % | Moderate % | n | Normal % | Mild % | Moderate % |
| ***Immediate causes*** | | | | | | | | | |
| Anthropometry | HAZ ≥-2 | 159 | 46.5 | 24.5 | 28.9* | 210 | 75.2 | 11.0 | 13.8* |
| | HAZ<-2 | 94 | 29.8 | 23.4 | 46.8 | 86 | 58.1 | 14.0 | 27.9 |
| | WAZ ≥-2 | 203 | 41.9 | 24.1 | 34.0 | 241 | 71.4 | 12.0 | 16.6 |
| | WAZ<-2 | 50 | 34.0 | 24.0 | 42.0 | 55 | 65.5 | 10.9 | 23.6 |
| | WHZ ≥-2 | 232 | 40.5 | 24.1 | 35.3 | 268 | 70.5 | 11.6 | 17.9 |
| | WHZ<-2 | 21 | 38.1 | 23.8 | 38.1 | 28 | 67.9 | 14.3 | 17.9 |
| Malaria parasitaemia | Negative | 225 | 40.4 | 24.4 | 35.1 | 272 | 71.0 | 11.0 | 18.0 |
| | Positive | 28 | 39.3 | 21.4 | 39.3 | 24 | 62.5 | 20.8 | 16.7 |
| Illness in last 2 days | No | 222 | 41.4 | 25.7 | 32.9* | 259 | 71.0 | 12.0 | 17.0 |
| | Yes | 31 | 32.3 | 12.9 | 54.8 | 37 | 64.9 | 10.8 | 24.3 |
| ***Underlying causes*** | | | | | | | | | |
| Child fully immunized | Yes | 195 | 41.5 | 21.0 | 37.4 | 250 | 69.6 | 11.6 | 18.8 |
| | No | 58 | 36.2 | 34.5 | 29.3 | 46 | 73.9 | 13.0 | 13.0 |
| Child iron supplements | No | 20† | 55.0 | 15.0 | 30.0 | 51 | 58.8 | 19.6 | 21.6 |
| | Yes | 228 | 39.0 | 25.0 | 36.0 | 245 | 72.7 | 10.2 | 17.1 |
| Protected water source | No | 66 | 48.5 | 25.8 | 25.8 | 66 | 78.8 | 7.6 | 13.6 |
| | Yes | 187 | 37.4 | 23.5 | 39.0 | 230 | 67.8 | 13.0 | 19.1 |
| Toilet type | Bush | 24 | 33.3 | 33.3 | 33.3 | 23 | 65.2 | 21.7 | 13.0 |
| | Shared/ communal | 132 | 38.6 | 24.2 | 37.1 | 153 | 66.7 | 12.4 | 20.9 |
| | Private/ improved | 97 | 44.3 | 21.6 | 34.0 | 120 | 75.8 | 9.2 | 15.0 |
| Own animals | No | 55 | 43.6 | 25.5 | 30.9 | 66† | 71.2 | 6.1 | 22.7 |
| | Yes | 198 | 39.4 | 23.7 | 36.9 | 229 | 69.9 | 13.5 | 16.6 |
| Produce/mainly consume ≥1 meat | No | 129 | 40.3 | 25.6 | 34.1 | 170 | 72.4 | 10.0 | 17.6 |
| | Yes | 124 | 40.3 | 22.6 | 37.1 | 126 | 67.5 | 14.3 | 18.3 |

*Continued on next page*

Table 6.2: Characteristics of children 24-59 mo by anaemia status, Ghana, *continued*

| Characteristic | | 2000 (N=253) | | | | 2004 (N=296) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | n | Normal % | Mild % | Moderate % | n | Normal % | Mild % | Moderate % |
| Child meat intake (7 d) | At least once | 125 | 44.0 | 24.0 | 32.0 | 194 | 70.6 | 13.9 | 15.5 |
| | None | 95† | 32.6 | 25.3 | 42.1 | 99† | 70.7 | 7.1 | 22.2 |
| Meat/fish known to prevent anaemia | No | 89† | 34.8 | 23.6 | 41.6 | 96† | 74.0 | 9.4 | 16.7 |
| | Yes | 153 | 43.8 | 23.5 | 32.7 | 198 | 68.7 | 13.1 | 18.2 |
| ***Basic causes*** | | | | | | | | | |
| Household wealth rank | Lowest 20% | 43 | 23.3 | 23.3 | 53.5* | 61 | 67.2 | 11.5 | 21.3 |
| | Middle 60% | 154 | 40.9 | 27.3 | 31.8 | 173 | 72.3 | 11.6 | 16.2 |
| | Highest 20% | 56 | 51.8 | 16.1 | 32.1 | 62 | 67.7 | 12.9 | 19.4 |
| Mother's age group | <30 yrs | 121 | 37.2 | 23.1 | 39.7 | 151† | 70.9 | 11.3 | 17.9 |
| | ≥30 yrs | 132 | 43.2 | 25.0 | 31.8 | 144 | 69.4 | 12.5 | 18.1 |
| Mother's education | None/ non-formal | 30 | 26.7 | 33.3 | 40.0 | 44 | 68.2 | 9.1 | 22.7 |
| | Primary/ above | 223 | 42.2 | 22.9 | 35.0 | 252 | 70.6 | 12.3 | 17.1 |
| Head education | None/ non-formal | 58 | 34.5 | 32.8 | 32.8 | 54 | 70.4 | 11.1 | 18.5 |
| | Primary/ above | 195 | 42.1 | 21.5 | 36.4 | 242 | 70.2 | 12.0 | 17.8 |
| Health facility distance | In village | 109 | 59.6 | 19.3 | 21.1** | 129 | 68.2 | 12.4 | 19.4 |
| | Within 5 km | 60 | 28.3 | 26.7 | 45.0 | 109 | 71.6 | 11.9 | 16.5 |
| | Over 5 km | 84 | 23.8 | 28.6 | 47.6 | 58 | 72.4 | 10.3 | 17.2 |
| ***Other child characteristics*** | | | | | | | | | |
| Child age group (months) | 24-35 | 105 | 43.8 | 18.1 | 38.1 | 116 | 68.1 | 11.2 | 20.7 |
| | 36-47 | 82 | 39.0 | 22.0 | 39.0 | 91 | 64.8 | 13.2 | 22.0 |
| | 48-59 | 66 | 36.4 | 36.4 | 27.3 | 89 | 78.7 | 11.2 | 10.1 |
| Child sex | Male | 129 | 44.2 | 24.0 | 31.8 | 161 | 69.6 | 12.4 | 18.0 |
| | Female | 124 | 36.3 | 24.2 | 39.5 | 135 | 71.1 | 11.1 | 17.8 |

* $p<0.05$, ** $p<0.001$ for chi-square test within each year

† Missing data for some cases

#### 6.2.1.2 Malawi

Table 6.3 shows the results of univariate analyses for children from Malawi. In this country context, a child's nutritional status was strongly related to risk of anaemia – stunted and underweight children had a higher prevalence of moderate/severe anaemia in 2000 and 2004. Malaria parasitaemia was associated with increased risk of moderate/severe anaemia in 2000.

Anaemia status did not vary by region in 2000, but in 2004, children from the Southern region had the highest prevalence of moderate/severe anaemia ($p<0.001$). A strong association between age and anaemia status was observed in 2004, with the youngest group (24-35 mo) having the highest prevalence of moderate/severe anaemia.

There was no association with anaemia status for child sex, recent illness, wasted status, immunization status, access to child iron supplementation, water source, type of toilet used, animal ownership, household wealth rank, maternal education level or age, household head education level or proximity to nearest health facility.

Table 6.3: Characteristics of children 24-59 mo by anaemia status, Malawi

| Characteristic | | 2000 (N=466) | | | | 2004 (N=679) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | n | Normal % | Mild % | Moderate % | n | Normal % | Mild % | Moderate % |
| ***Immediate causes*** | | | | | | | | | |
| Anthropometry | HAZ ≥-2 | 197 | 43.7 | 19.8 | 36.5* | 303 | 47.2 | 25.7 | 27.1* |
| | HAZ<-2 | 269 | 32.0 | 22.7 | 45.4 | 376 | 37.8 | 25.3 | 37.0 |
| | WAZ ≥-2 | 341 | 39.3 | 20.5 | 40.2 | 627 | 43.4 | 25.5 | 31.1* |
| | WAZ<-2 | 125 | 30.4 | 24.0 | 45.6 | 52 | 25.0 | 25.0 | 50.0 |
| | WHZ ≥-2 | 429 | 36.1 | 21.7 | 42.2 | 675 | 41.9 | 25.6 | 32.4 |
| | WHZ<-2 | 37 | 45.9 | 18.9 | 35.1 | 4 | 50.0 | 0 | 50.0 |
| Malaria parasitaemia | Negative | 318 | 45.6 | 21.1 | 33.3** | 588 | 43.2 | 25.3 | 31.5 |
| | Positive | 148 | 18.2 | 22.3 | 59.5 | 91 | 34.1 | 26.4 | 39.6 |
| Illness in last 2 days | No | 327 | 37.9 | 22.3 | 39.8 | 550 | 43.6 | 25.8 | 30.5 |
| | Yes | 139 | 34.5 | 19.4 | 46.0 | 129 | 34.9 | 24.0 | 41.1 |
| ***Underlying causes*** | | | | | | | | | |
| Child fully immunized | No | 65 | 43.1 | 21.5 | 35.4 | 15 | 53.3 | 20.0 | 26.7 |
| | Yes | 401 | 35.9 | 21.4 | 42.6 | 664 | 41.7 | 25.6 | 32.7 |
| Child iron supplements | No | N/A | | | | 159† | 46.5 | 25.8 | 27.7 |
| | Yes | N/A | | | | 450 | 40.4 | 25.8 | 33.8 |
| Protected water source | No | 67 | 32.8 | 28.4 | 38.8 | 116 | 40.5 | 21.6 | 37.9 |
| | Yes | 399 | 37.6 | 20.3 | 42.1 | 563 | 42.3 | 26.3 | 31.4 |
| Toilet type | Bush | 50 | 40.0 | 20.0 | 40.0 | 37 | 37.8 | 37.8 | 24.3 |
| | Shared/ communal | 57 | 38.6 | 12.3 | 49.1 | 101 | 47.5 | 23.8 | 28.7 |
| | Private/ improved | 359 | 36.2 | 23.1 | 40.7 | 541 | 41.2 | 25.0 | 33.8 |
| Own animals | No | 145† | 40.7 | 17.9 | 41.4 | 189 | 41.8 | 29.6 | 28.6 |
| | Yes | 321 | 35.2 | 23.1 | 41.7 | 490 | 42.0 | 23.9 | 34.1 |
| ***Basic causes*** | | | | | | | | | |
| Household wealth rank | Low | 88 | 38.6 | 23.9 | 37.5 | 142 | 39.4 | 26.1 | 34.5 |
| | Middle | 287 | 38.3 | 19.2 | 42.5 | 403 | 41.4 | 25.8 | 32.8 |
| | High | 91 | 30.8 | 26.4 | 42.9 | 134 | 46.3 | 23.9 | 29.9 |
| Mother's age group | <30 yrs | 244 | 39.3 | 20.9 | 39.8 | 386 | 42.2 | 27.7 | 30.1 |
| | ≥30 yrs | 222 | 34.2 | 22.1 | 43.7 | 293 | 41.6 | 22.5 | 35.8 |

*Continued on next page*

Table 6.3: Characteristics of children 24-59 mo by anaemia status, Malawi *(continued)*

| Characteristic | | 2000 (N=466) | | | | 2004 (N=679) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | n | Normal % | Mild % | Moderate % | n | Normal % | Mild % | Moderate % |
| Mother's education level | None/ non-formal | 168 | 33.3 | 22.0 | 44.6 | 160 | 37.5 | 26.9 | 35.6 |
| | Primary/ above | 298 | 38.9 | 21.1 | 39.9 | 519 | 43.4 | 25.0 | 31.6 |
| Head education level | None/ non-formal | 108 † | 37.0 | 27.8 | 35.2 | 77 | 36.4 | 31.2 | 32.5 |
| | Primary/ above | 358 | 36.9 | 19.6 | 43.6 | 592 | 42.6 | 24.7 | 32.8 |
| Health facility distance[1] | In village | 131 | 31.3 | 20.6 | 48.1 | 159 | 41.5 | 24.5 | 34.0 |
| | Within 1 hr/ 2-6 km | 65 | 38.5 | 24.6 | 36.9 | 347 | 45.2 | 25.9 | 28.8 |
| | Over 1 hr/6 km | 270 | 39.3 | 21.1 | 39.6 | 173 | 35.8 | 25.4 | 38.7 |
| Region | North | 74 | 33.8 | 23.0 | 43.2 | 126 | 47.6 | 29.4 | 23.0** |
| | Central | 92 | 35.9 | 23.9 | 40.2 | 370 | 46.2 | 23.5 | 30.3 |
| | South | 300 | 38.0 | 20.3 | 41.7 | 183 | 29.5 | 26.8 | 43.7 |
| ***Other child characteristics*** | | | | | | | | | |
| Child age group (months) | 24-35 | 237 | 35.9 | 21.1 | 43.0 | 270 | 36.3 | 24.8 | 38.9* |
| | 36-47 | 150 | 34.7 | 23.3 | 42.0 | 243 | 40.7 | 26.3 | 32.9 |
| | 48-59 | 79 | 44.3 | 19.0 | 36.7 | 166 | 53.0 | 25.3 | 21.7 |
| Child sex | Male | 233 | 34.8 | 21.9 | 43.3 | 351 | 41.0 | 27.4 | 31.6 |
| | Female | 233 | 39.1 | 21.0 | 39.9 | 328 | 43.0 | 23.5 | 33.5 |

* $p<0.05$, ** $p<0.001$ for chi-square test within each year

† Missing data for some cases

[1] 2000 data based on village-level response quantified in time to walk; 2004 data based on household-level response quantified in kilometres.

#### 6.2.1.3 Tanzania

Table 6.4 presents the results of the univariate analyses of risk factors associated with anaemia status for children from Tanzania. Due to a small sample size in 2004, the power to detect statistically significant associations was limited. In this country context, a higher proportion of moderate/severe anaemia was observed among children who were undernourished and those with malaria parasitaemia and recent illness but these associations did not reach statistical significance in these samples.

In terms of program targeted practices, a strong association with type of toilet used was observed but only in 2000, with highest levels of moderate/severe anaemia among those using the bush or field. There was no association with anaemia status for indicators of immunization status, animal ownership, animal food production/consumption or child iron supplementation (2004 only).

There was an association between age and anaemia status in 2000, with the youngest children (24-35 mo) having the highest prevalence of moderate/severe anaemia. A similar age-related pattern was observed in the 2004 sample, although it failed to reach statistical significance.

No association with anaemia status was evident for household wealth rank, program division, proximity to health facility, maternal age group, maternal and household head education and child sex.

Table 6.4: Characteristics of children 24-59 mo by anaemia status, Tanzania

| Characteristic | | **2000** (N=634) | | | | **2004** (N=77) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **n** | **Normal %** | **Mild %** | **Moderate %** | **n** | **Normal %** | **Mild %** | **Moderate %** |
| ***Immediate causes*** | | | | | | | | | |
| Anthropometry | HAZ ≥-2 | 219 | 24.2 | 22.8 | 53.0 | 36 | 41.7 | 19.4 | 38.9 |
| | HAZ<-2 | 415 | 21.7 | 22.4 | 55.9 | 41 | 31.7 | 24.4 | 43.9 |
| | WAZ ≥-2 | 502 | 23.1 | 23.1 | 53.8 | 53 | 37.7 | 26.4 | 35.8 |
| | WAZ<-2 | 132 | 20.5 | 20.5 | 59.1 | 24 | 33.3 | 12.5 | 54.2 |
| | WHZ ≥-2 | 622 | 22.8 | 22.8 | 54.3 | 70 | 34.3 | 24.3 | 41.4 |
| | WHZ<-2 | 12 | 8.3 | 8.3 | 83.3 | 7 | 57.1 | 0 | 42.9 |
| Malaria parasitaemia | Negative | 566 | 22.3 | 23.5 | 54.2 | 63 | 36.5 | 23.8 | 39.7 |
| | Positive | 68 | 25.0 | 14.7 | 60.3 | 14 | 35.7 | 14.3 | 50.0 |
| Illness in last 2 days | No | 291 | 24.1 | 25.4 | 50.5 | 51 | 41.2 | 23.5 | 35.3 |
| | Yes | 343 | 21.3 | 20.1 | 58.6 | 26 | 26.9 | 19.2 | 53.8 |
| ***Underlying causes*** | | | | | | | | | |
| Child fully immunized | No | 86 | 19.8 | 22.1 | 58.1 | 15 | 46.7 | 13.3 | 40.0 |
| | Yes | 548 | 23.0 | 22.6 | 54.4 | 62 | 33.9 | 24.2 | 41.9 |
| Child iron supplements | No | N/A | | | | 44† | 36.4 | 22.7 | 40.9 |
| | Yes | N/A | | | | 25 | 48.0 | 20.0 | 32.0 |
| Protected water source | No | 333 | 21.6 | 24.6 | 53.8 | 44 | 40.9 | 25.0 | 34.1 |
| | Yes | 301 | 23.6 | 20.3 | 56.1 | 33 | 30.3 | 18.2 | 51.5 |
| Toilet type | Bush | 66 | 12.1 | 13.6 | 74.2* | 4 | 25.0 | 50.0 | 25.0 |
| | Shared/ communal | 89 | 28.1 | 18.0 | 53.9 | 24 | 37.5 | 20.8 | 41.7 |
| | Private/ improved | 479 | 23.0 | 24.6 | 52.4 | 49 | 36.7 | 20.4 | 42.9 |
| Own animals | No | 250† | 23.6 | 22.4 | 54.0 | 33 | 30.3 | 27.3 | 42.4 |
| | Yes | 381 | 21.8 | 22.8 | 55.4 | 44 | 40.9 | 18.2 | 40.9 |
| Produce/mainly consume ≥1 meat | No | 211† | 21.8 | 23.2 | 55.0 | 31† | 41.9 | 16.1 | 41.9 |
| | Yes | 179 | 22.3 | 22.3 | 55.3 | 13 | 38.5 | 23.1 | 38.5 |
| Child liver intake in past 7 d | None | 459† | 22.7 | 23.7 | 53.6 | 58† | 34.5 | 27.6 | 37.9 |
| | At least once | 77 | 26.0 | 18.2 | 55.8 | 10 | 40.0 | 10.0 | 50.0 |

*Continued on next page*

Table 6.4: Characteristics of children 24-59 mo by anaemia status, Tanzania, *continued*

| Characteristic | | **2000** (N=634) | | | | **2004** (N=77) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **n** | **Normal %** | **Mild %** | **Moderate %** | **n** | **Normal %** | **Mild %** | **Moderate %** |
| ***Basic causes*** | | | | | | | | | |
| Wealth rank | Lowest 20% | 135 | 20.0 | 19.3 | 60.7 | 18 | 11.1 | 33.3 | 55.6 |
| | Middle 60% | 381 | 23.1 | 22.8 | 54.1 | 43 | 39.5 | 23.3 | 37.2 |
| | Highest 20% | 118 | 23.7 | 25.4 | 50.8 | 16 | 56.2 | 6.2 | 37.5 |
| Maternal age group | <30 yrs | 345 | 23.2 | 21.7 | 55.1 | 33 | 27.3 | 24.2 | 48.5 |
| | ≥30 yrs | 289 | 21.8 | 23.5 | 54.7 | 44 | 43.2 | 20.5 | 36.4 |
| Maternal education level | None/non-formal | 167 | 19.2 | 22.8 | 58.1 | 18 | 33.3 | 33.3 | 33.3 |
| | Primary/above | 467 | 23.8 | 22.5 | 53.7 | 59 | 37.3 | 18.6 | 44.1 |
| Head education level | None/non-formal | 79 | 17.7 | 19.0 | 63.3 | 14 | 50.0 | 14.3 | 35.7 |
| | Primary/above | 555 | 23.2 | 23.1 | 53.7 | 63 | 33.3 | 23.8 | 42.9 |
| Health facility distance[1] | In village | 465 | 23.2 | 23.0 | 53.8 | 43 | 34.9 | 23.3 | 41.9 |
| | Within 5 km | 106 | 18.9 | 24.5 | 56.6 | 14 | 28.6 | 14.3 | 57.1 |
| | Over 5 km | 63 | 23.8 | 15.9 | 60.3 | 20 | 45.0 | 25.0 | 30.0 |
| Division | Mombo | 236 | 22.5 | 22.9 | 54.7 | 30 | 46.7 | 10.0 | 43.3 |
| | Mazingara | 98 | 18.4 | 19.4 | 62.2 | 22 | 27.3 | 31.8 | 40.9 |
| | Mzundu | 179 | 19.0 | 22.9 | 58.1 | 11 | 27.3 | 36.4 | 36.4 |
| | Sindeni | 121 | 31.4 | 24.0 | 44.6 | 14 | 35.7 | 21.4 | 42.9 |
| ***Other child characteristics*** | | | | | | | | | |
| Child age group (months) | 24-35 | 213 | 19.2 | 20.7 | 60.1* | 32 | 25.0 | 21.9 | 53.1 |
| | 36-47 | 230 | 23.0 | 19.6 | 57.4 | 23 | 39.1 | 26.1 | 34.8 |
| | 48-59 | 191 | 25.7 | 28.3 | 46.1 | 22 | 50.0 | 18.2 | 31.8 |
| Child sex | Male | 318 | 23.3 | 23.3 | 53.5 | 40 | 32.5 | 17.5 | 50.0 |
| | Female | 316 | 21.8 | 21.8 | 56.3 | 37 | 40.5 | 27.0 | 32.4 |

* $p<0.05$, ** $p<0.001$ for chi-square test within each year

† Missing data for some cases

[1] 2000 data based on village-level response; 2004 data based on household-level response.

### 6.2.2 Factors associated with anaemia status in multiple regression analysis

Results from the individual country multinomial logistic regression models are shown in Table 6.5, showing the corrected risk ratio estimates for risk factors for mild and moderate/severe anaemia among children 24-59 mo. Estimates showed very little change in the log-odds estimates across the models as blocks of variables were added; therefore, only the results for the full model are presented. (Detailed results by block for each country are presented in Appendix H.) The full model accounted for a larger proportion of the variance in the Ghana data set (pseudo R-square 0.19) than the Malawi and Tanzania datasets. The risk of anaemia was poorly explained by the full model in both of these datasets (pseudo R-square 0.08 and 0.07, respectively) and the Tanzania model was not very stable, likely due to a small number of cases in 2004 (n=77).

#### 6.2.2.1 Change in risk of anaemia between 2000 and 2004

In Ghana, the risk of mild and moderate/severe anaemia was over two times higher in 2000 compared to 2004. There was no significant difference in the risk of any type of anaemia in Malawi between 2000 and 2004. The risk of moderate/severe anaemia was higher in Tanzania in 2000 compared to 2004, with a RR of 1.39 (95% CI 1.05, 1.71).

#### 6.2.2.2 Risk associated with immediate causes

Stunting was a significant risk factor for moderate/severe anaemia in both Ghana and Malawi, with a RR of 2.00 (95% CI 1.49, 2.55) and 1.40 (95% CI 1.18, 1.63), respectively. The risk of mild anaemia among stunted compared to non-stunted children was in a similar direction in both countries but the 95% CI for RR estimates included one. In contrast, there was little evidence in the Tanzania data for a role of stunting in increasing the risk of either mild or moderate/severe anaemia.

Malaria parasitaemia was a significant risk factor for both mild (RR 1.54, 95% CI 1.17, 1.96) and moderate/severe (RR 1.79, 95% CI 1.50, 2.05) anaemia in Malawi but not in Ghana or Tanzania. Recent illness also increased a child's risk of

moderate/severe but not mild anaemia in Malawi; children sick in the last two days were 1.3 times more likely to have moderate/severe anaemia than those who were not sick. Children who were sick in the last two days were not at significantly greater risk of mild or moderate/severe anaemia in either Ghana or Tanzania.

#### 6.2.2.3 Risk associated with underlying causes

There was no evidence for an increased risk of anaemia associated with household water source in any country. But there was evidence of an increased risk of mild anaemia in Ghana and moderate/severe anaemia in Tanzania among children from households who reported using the bush or field as a toilet, independent of recent illness. Toilet type was not associated with an increased risk of anaemia in Malawi.

#### 6.2.2.4 Risk associated with basic causes

The variables representing basic causes of anaemia appeared to have little remaining direct role in the risk of anaemia, with the exception of proximity of the child's household to a health facility. Living in a community without a health facility was associated with an increased risk of moderate/severe anaemia in Ghana. The risk of being moderately/severely anaemic was nearly two times higher for children living in communities over 5 km from the nearest health facility (RR 1.93; 95% CI 1.33, 2.60) compared to those living in a community with a health facility; living within 5 km was associated with a RR of 1.55 (95% CI 1.05, 2.16). In Malawi, children were at lower risk of moderate/severe anaemia if they lived in a community where the nearest health facility was within 5 km versus those who lived in a community with a health facility.

#### 6.2.2.5 Risk associated with child age and sex

The risk of moderate/severe anaemia was lower for children in the oldest age group (48-59 mo) compared to children 24-35 mo across all three countries, with the RR ranging from 0.57 in Malawi to 0.64 in Ghana and 0.69 in Tanzania. Risk of moderate/severe anaemia was similar for the two youngest groups. No evidence of an association with age was observed for mild anaemia in any of the countries. Consistent with the univariate results, child sex showed no association with the risk of any type of anaemia in multiple regression models.

Table 6.5: Corrected risk ratio estimates (95% CI) of risk factors for anaemia in children 24-59 mo by country[1]

| Variable | Ghana[2] | | Malawi[3] | | Tanzania[4] | |
|---|---|---|---|---|---|---|
| | **Mild anaemia** | **Mod/Sev anaemia** | **Mild anaemia** | **Mod/Sev anaemia** | **Mild anaemia** | **Mod/Sev anaemia** |
| **Immediate causes** | | | | | | |
| Stunted v. Non-stunted | 1.47 (0.97, 2.13) | **2.00 (1.49, 2.55)** | 1.22 (0.97, 1.51) | **1.40 (1.18, 1.63)** | 1.14 (0.79, 1.58) | 1.12 (0.93, 1.31) |
| Malaria positive v. negative | 1.28 (0.65, 2.24) | 1.02 (0.56, 1.65) | **1.54 (1.17, 1.96)** | **1.79 (1.50, 2.05)** | 0.62 (0.31, 1.13) | 1.04 (0.78, 1.29) |
| Recent illness yes v. no | 0.71 (0.33, 1.41) | 1.46 (0.94, 2.09) | 1.05 (0.79, 1.38) | **1.28 (1.05, 1.51)** | 0.94 (0.66, 1.29) | 1.16 (0.97, 1.35) |
| **Underlying causes** | | | | | | |
| Non-potable water source v. potable | 0.77 (0.46, 1.23) | 0.69 (0.44, 1.04) | 1.05 (0.74, 1.41) | 1.11 (0.87, 1.38) | 1.18 (0.82, 1.62) | 0.99 (0.81, 1.15) |
| No toilet v. private | **2.03 (1.03, 3.40)** | 1.10 (0.54, 1.95) | 1.06 (0.66, 1.57) | 0.82 (0.53, 1.17) | 0.98 (0.45, 1.85) | **1.53 (1.01, 2.01)** |
| Shared toilet v. private | 1.28 (0.82, 1.92) | 1.09 (0.75, 1.52) | 0.76 (0.52, 1.10) | 0.93 (0.70, 1.19) | 0.67 (0.39, 1.10) | 0.84 (0.58, 1.15) |
| **Basic causes** | | | | | | |
| Low wealth rank v. High | 1.11 (0.53, 2.11) | 1.25 (0.75, 1.89) | 0.95 (0.64, 1.36) | 0.93 (0.66, 1.24) | 1.15 (0.63, 1.86) | 1.20 (0.89, 1.48) |
| Middle wealth rank v. high | 1.22 (0.70, 2.00) | 0.82 (0.51, 1.23) | 0.92 (0.67, 1.22) | 0.99 (0.77, 1.24) | 1.02 (0.64, 1.52) | 1.07 (0.82, 1.30) |
| Mother no formal education v. some | 1.13 (0.62, 1.92) | 1.12 (0.68, 1.70) | 1.19 (0.91, 1.50) | 1.21 (0.99, 1.43) | 1.23 (0.82, 1.76) | 1.05 (0.84, 1.26) |
| Health facility over 5 km v. in village | 1.62 (0.996, 2.46) | **1.93 (1.33, 2.60)** | 1.01 (0.72, 1.36) | 0.99 (0.79, 1.21) | 0.79 (0.42, 1.36) | 1.06 (0.79, 1.31) |
| Health facility within 5 km v. in village | 1.31 (0.80, 2.02) | **1.55 (1.05, 2.16)** | 0.94 (0.67, 1.26) | **0.76 (0.59, 0.98)** | 1.20 (0.73, 1.80) | 1.14 (0.88, 1.36) |
| **Survey year** | | | | | | |
| 2000 v. 2004 | **2.71 (1.88, 3.70)** | **2.41 (1.83, 3.04)** | 0.83 (0.61, 1.08) | 0.95 (0.75, 1.17) | 1.30 (0.77, 2.00) | **1.39 (1.05, 1.71)** |

*Continued on next page*

Table 6.5: Corrected risk ratio estimates (95% CI) of risk factors for anaemia in children 24-59 mo by country, *continued*

| Variable | Ghana[1] | | Malawi[2] | | Tanzania[3] | |
|---|---|---|---|---|---|---|
| | **Mild anaemia** | **Mod/Sev anaemia** | **Mild anaemia** | **Mod/Sev anaemia** | **Mild anaemia** | **Mod/Sev anaemia** |
| **Other child characteristics** | | | | | | |
| 48-59 mo v. 24-35 mo | 1.41 (0.86, 2.19) | **0.64 (0.39, 0.99)** | 0.73 (0.52, 1.01) | **0.57 (0.42, 0.75)** | 0.88 (0.55, 1.34) | **0.69 (0.51, 0.89)** |
| 36-47 mo v. 24-35 mo | 1.20 (0.71, 1.91) | 1.02 (0.70, 1.41) | 1.01 (0.76, 1.30) | 0.90 (0.73, 1.09) | 0.81 (0.50, 1.24) | 0.86 (0.68, 1.05) |
| Female v. Male | 1.03 (0.68, 1.50) | 1.17 (0.84, 1.57) | 0.88 (0.69, 1.10) | 0.98 (0.81, 1.16) | 0.98 (0.69, 1.37) | 1.00 (0.83, 1.18) |

[1] Corrected risk ratios estimated from adjusted odds ratios (multinomial logistic regression model) using method of Zhang & Yu (1998). Numbers in **bold** font are significant at the $p<0.05$ level.

[2] Model based on N=549, normal 310 (56.5%); mild 96 (17.5%); moderate/severe 143 (26.0%). Pseudo R-Square (Cox and Snell) = 0.19.

[3] Model based on N=1145, normal 457 (39.9%); mild 273 (23.8%); moderate/severe 415 (36.2%). Pseudo R-Square (Cox and Snell) = 0.08.

[4] Model based on N=711, normal 171 (24.1%); mild 160 (22.5%); moderate/severe 380 (53.4%); model not very stable, likely due to low number of cases in 2004 (n=77). Pseudo R-Square (Cox and Snell) = 0.07.

### 6.2.3 Magnitude of association with mean haemoglobin

Estimates of the magnitude of association with mean haemoglobin for known risk factors for anaemia using a pooled data set are presented here. Table 6.6 shows the one-way ANOVA results for the association with mean haemoglobin levels of various factors by year. In 2000 and 2004, mean haemoglobin levels were lower among children from Tanzania, who were stunted, underweight, malaria positive, recently ill and younger in age. Child wasted status and sex, household potable water source and wealth rank, maternal education level and distance to health facility were not associated with mean haemoglobin levels in 2000 or 2004. There was some evidence for lower mean haemoglobin among children whose household used a private/improved toilet type, but only in the 2004 sample.

Results of multiple linear regression models are presented in Table 6.7, with one block of variables added with each additional model[22]. The estimated difference in mean haemoglobin associated with each risk factor is presented along with its 95% CI. Estimates did not change appreciably across the four models for any risk factor and therefore the results of Model 4 are the focus of the results presented here.

Children assessed in 2000 had significantly lower haemoglobin levels than children in 2004, with a difference of -3.30 g/L (95% CI -4.84, -1.76) in Model 4. Children from Tanzania and Malawi also had lower mean haemoglobin levels compared to children in Ghana. Children in the older two age groups had significantly higher haemoglobin levels compared to the youngest group, particularly children 48-59 mo (mean difference 5.43 g/L, 95% CI 3.77, 7.09).

Besides the variation in mean haemoglobin associated with year and country, only the variables that are conceptually considered immediate causes of anaemia and child age group have a significant association with mean haemoglobin levels. Estimates of adjusted means across all four models indicate significantly lower haemoglobin levels in children who are stunted, malaria positive and recently ill, even when controlling for

[22] Underweight and wasted status variables were not entered into the model due to concerns with high colinearity with stunted status.

age, sex and other underlying and basic causes of anaemia. These three factors are associated with a similar decrease in mean haemoglobin across all models. Notably, the difference in mean haemoglobin between children 48-59 mo and children 24-35 mo is of equal or greater magnitude compared to the difference associated with stunting, malaria parasitaemia or recent illness. Consistent with the univariate analysis, the associations of underlying causes of anaemia on which the program acted and basic causes such as socioeconomic status are negligible.

When two-way interaction terms for survey year with country, stunting, malaria and recent illness are added to the full model (Model 4), there is evidence for variation by year in the association of country and malaria with mean haemoglobin, but not for stunting or recent illness. Examination of these two-way interaction terms (year with stunting, malaria and recent illness) in each country dataset confirmed that there is no evidence for variation between years for the association of stunting with haemoglobin in any of the countries. However, there is evidence for variation between 2000 and 2004 in the association of mean haemoglobin with malaria in Malawi and recent illness in Ghana. These results by country and year are presented below.

Figure 6.3 presents a comparison of the marginal means across countries and years for children with and without malaria parasitaemia. Malawian children with malaria parasitaemia had lower mean haemoglobin levels (difference -9.81 g/L; 95% CI -13.02, -6.59; $p<0.001$) compared to those without malaria in 2000, but this large deficit was no longer evident in 2004 (difference -3.06 g/L; 95% CI -6.69, 0.57; $p=0.098$), due in part to an observed tendency for a higher mean haemoglobin level among children with malaria in 2004. There was no association of malaria status with mean haemoglobin in Ghana or Tanzania, likely due to wide confidence intervals for these estimates.

Table 6.6: Factors associated with haemoglobin (Hb) in children 24-59 mo (N=2405)

| Variable | | 2000 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | Mean Hb (g/L) | 95% CI | p-value* | N | Mean Hb (g/L) | 95% CI | p-value* |
| Country | Ghana | 253 | 104.98 | 103.04, 106.94 | <0.001 | 296 | 113.68 | 112.09, 115.27 | <0.001 |
| | Malawi | 466 | 103.14 | 101.54, 104.73 | | 679 | 105.88 | 104.65, 107.12 | |
| | Tanzania | 634 | 96.94 | 95.59, 98.30 | | 77 | 102.14 | 98.79, 105.49 | |
| Stunted status | No | 575 | 102.85 | 101.39, 104.32 | <0.001 | 549 | 110.36 | 109.08, 111.63 | <0.001 |
| | Yes | 778 | 98.90 | 97.71, 100.10 | | 503 | 105.02 | 103.57, 106.46 | |
| Underweight status | No | 1046 | 101.16 | 100.09, 102.24 | 0.024 | 921 | 108.38 | 107.36, 109.40 | 0.002 |
| | Yes | 307 | 98.59 | 96.74, 100.45 | | 131 | 103.73 | 100.72, 106.73 | |
| Wasted status | No | 1283 | 100.50 | 99.55, 101.45 | 0.478 | 1013 | 107.71 | 106.72, 108.70 | 0.358 |
| | Yes | 70 | 102.03 | 97.38, 106.68 | | 39 | 110.13 | 104.67, 115.59 | |
| Malaria status | No | 1109 | 101.35 | 100.32, 102.38 | 0.001 | 923 | 108.31 | 107.31, 109.31 | 0.006 |
| | Yes | 244 | 97.08 | 94.92, 99.25 | | 129 | 104.16 | 100.78, 107.55 | |
| Illness in last 2 days | No | 840 | 102.47 | 101.31, 103.64 | <0.001 | 860 | 108.70 | 107.62, 109.78 | 0.0001 |
| | Yes | 513 | 97.48 | 95.96, 99.01 | | 192 | 103.79 | 101.62, 105.97 | |
| Potable water source | No | 466 | 99.48 | 97.93, 101.04 | 0.095 | 226 | 108.54 | 106.26, 110.81 | 0.437 |
| | Yes | 887 | 101.16 | 99.99, 102.32 | | 826 | 107.60 | 106.53, 108.67 | |

*Continued on next page*

Table 6.6: Factors associated with haemoglobin (Hb) in children 24-59 mo (N=2405), *continued*

| **Variable** | | **2000** | | | | **2004** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **N** | **Mean Hb (g/L)** | **95% CI** | **p-value*** | **N** | **Mean Hb (g/L)** | **95% CI** | **p-value*** |
| Toilet type | Bush/ground | 140 | 97.88 | 94.96, 100.80 | 0.146 | 64 | 110.22 | 106.49, 113.95 | 0.027 |
| | Shared/communal | 278 | 101.22 | 99.16, 103.29 | | 278 | 109.59 | 107.76, 111.43 | |
| | Private/improved | 935 | 100.79 | 99.67, 101.91 | | 710 | 106.88 | 105.68, 108.08 | |
| Wealth rank | Lowest | 266 | 99.34 | 97.20, 101.49 | 0.226 | 221 | 107.00 | 104.62, 109.37 | 0.402 |
| | Middle | 822 | 100.54 | 99.33, 101.74 | | 619 | 107.67 | 106.45, 108.89 | |
| | Highest | 265 | 101.96 | 99.94, 103.98 | | 212 | 109.03 | 106.89, 111.17 | |
| Maternal education level | None or non-formal | 365 | 99.33 | 97.53, 101.14 | 0.111 | 222 | 106.94 | 104.83, 109.05 | 0.368 |
| | Primary or above | 988 | 101.04 | 99.95, 102.13 | | 830 | 108.03 | 106.94, 109.13 | |
| Health facility distance | In village | 705 | 99.94 | 98.59, 101.29 | 0.182 | 331 | 107.67 | 105.89, 109.45 | 0.313 |
| | Within 5 km | 231 | 100.17 | 98.23, 102.11 | | 470 | 108.53 | 107.05, 110.01 | |
| | Over 5 km | 417 | 101.89 | 100.23, 103.55 | | 251 | 106.62 | 104.76, 108.48 | |
| Age group | 24-35 mo | 555 | 99.36 | 97.83, 100.88 | 0.015 | 418 | 105.38 | 103.77, 106.98 | <0.001 |
| | 36-47 mo | 462 | 100.41 | 98.85, 101.98 | | 357 | 107.15 | 105.50, 108.79 | |
| | 48-59 mo | 336 | 102.83 | 101.08, 104.59 | | 277 | 112.31 | 110.60, 114.01 | |
| Sex | Male | 680 | 100.69 | 99.32, 102.06 | 0.815 | 552 | 107.89 | 106.54, 109.23 | 0.860 |
| | Female | 673 | 100.47 | 99.21, 101.73 | | 500 | 107.71 | 106.30, 109.12 | |

* Level of significance associated with the F-test for one-way ANOVA.

Table 6.7: Difference in mean Hb (g/L) based on multivariate models (N=2405)

| **Variable** | | **Difference in Hb mean (g/L) by Model** | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Survey year | (2000 v. 2004) | **-4.48**** (-5.95, -3.01) | **-3.58**** (-5.05, -2.11) | **-3.54**** (-5.02, -2.06) | **-3.30**** (-4.84, -1.76) |
| Country | (TZ v. GH) | **-10.40**** (-12.34, -8.46) | **-8.44**** (-10.47, -6.41) | **-8.95**** (-11.12, -6.78) | **-9.15**** (-11.36, -6.94) |
| | (MW v. GH) | **-4.83**** (-6.50, -3.15) | **-3.15**** (-4.86, -1.43) | **-3.31**** (-5.15, -1.46) | **-2.96*** (-4.85, -1.07) |
| Age group | (36-47 v. 24-35) | **1.77**** (0.24, 3.31) | **1.62*** (0.10, 3.15) | **1.63*** (0.11, 3.16) | **1.62*** (0.10, 3.15) |
| | (48-59 v. 24-35) | **5.48**** (3.81, 7.15) | **5.37**** (3.72, 7.03) | **5.35**** (3.69, 7.01) | **5.43**** (3.77, 7.09) |
| Sex | (female v. male) | -0.03 (-1.35, 1.29) | -0.30 (-1.61, 1.00) | -0.33 (-1.63, 0.98) | -0.31 (-1.62, 1.00) |
| Stunted status | (yes v. no) | | **-3.42**** (-4.76, -2.07) | **-3.36**** (-4.71, -2.02) | **-3.33**** (-4.69, -1.98) |
| Malaria status | (yes v. no) | | **-4.37**** (-6.20, -2.54) | **-4.38**** (-6.21, -2.55) | **-4.42**** (-6.26, -2.59) |
| Illness in last 2 days | (yes v. no) | | **-2.99**** (-4.51, -1.46) | **-2.93**** (-4.45, -1.40) | **-2.89**** (-4.42, -1.36) |
| Potable water source | (yes v. no) | | | -0.95 (-0.59, 2.50) | 0.93 (-0.62, 2.48) |
| Toilet type | (bush v. private) | | | -1.35 (-3.74, 1.05) | -1.16 (-3.61, 1.29) |
| | (shared v. private) | | | -0.55 (-2.24, 1.14) | -0.41 (-2.12, 1.29) |
| Wealth rank | (low v. high) | | | | -0.86 (-3.01, 1.29) |
| | (middle v. high) | | | | -0.88 (-2.58, 0.83) |
| Maternal education | (none v. primary+) | | | | -0.59 (-2.16, 0.98) |
| Health facility distance | (≤5km v. in village) | | | | -0.26 (-1.93, 1.42) |
| | (>5km v. in village) | | | | -1.30 (-3.02, 0.42) |

*p<0.05; **p<0.001

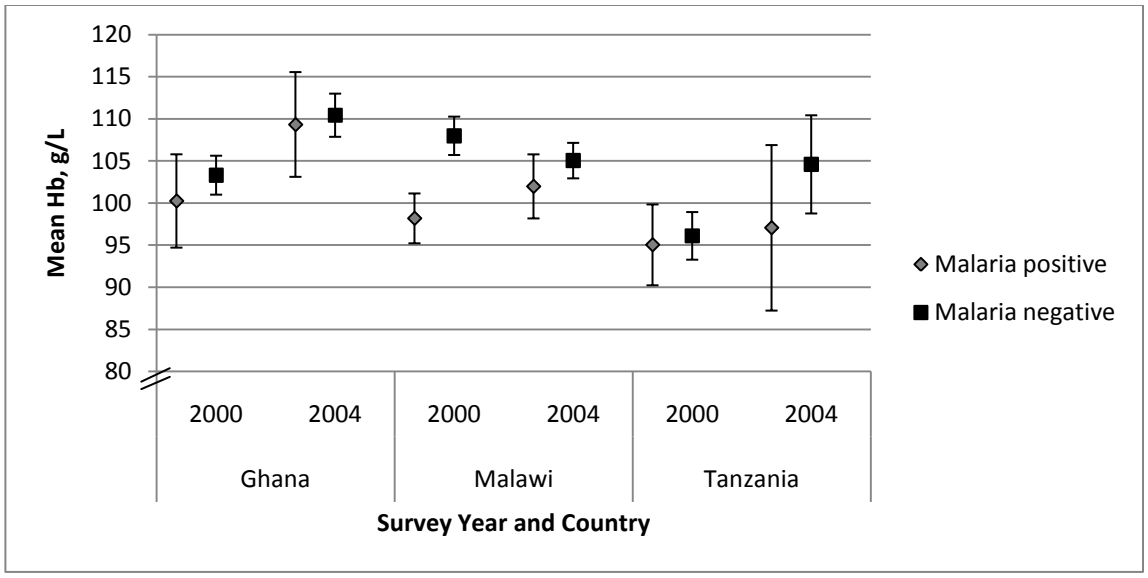



Figure 6.3: Comparison of mean haemoglobin among children with and without malaria parasitaemia by year and country

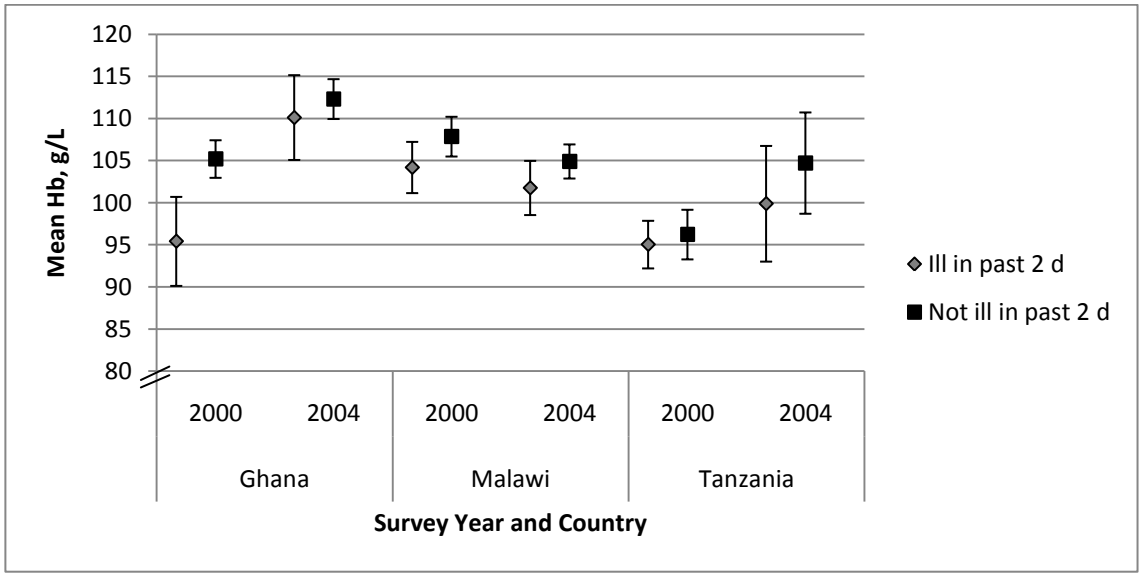



Figure 6.4: Comparison of mean haemoglobin among children with and without illness in the previous two days by year and country

Evidence of variation between 2000 and 2004 in the association between recent illness and mean haemoglobin was found only in Ghana, as shown in Figure 6.4. In this country context, children who were reported to be ill in the past two days had a markedly lower mean haemoglobin level in 2000 compared to those who had not been

ill (difference -9.78 g/L; 95% CI -15.20, -4.36; p<0.001). However, in 2004, the mean haemoglobin level of children who were ill in the past two days was much higher compared to those who were ill in 2000 (difference +14.70 g/L, 95% CI 7.52, 21.89; p<0.001) and no longer different from children in 2004 who were not ill (difference 2.19 g/L; 95% CI -2.80, 7.19; p=0.389).

## 6.3 Public health importance of undernutrition and morbidity in anaemia control efforts

In order to better understand the relative public health importance of addressing child undernutrition and morbidity in the context of anaemia control programs, comparisons were made for the difference in prevalence of stunting, malaria and recent illness between 2000 and 2004 in each country and the relative risk of mild and moderate/severe anaemia.

### 6.3.1 Difference in prevalence stratified by child health status

A comparison of the differences in prevalence of mild and moderate/severe anaemia between 2000 and 2004 for children in the study, stratified by their stunted, malaria or recent illness status is shown in Figure 6.5. Differences greater than zero indicate a higher prevalence and differences less than zero indicate a lower prevalence in 2004 compared to 2000 for each subgroup.

The top portion of the figure shows the difference observed among stunted vs. non-stunted children. In all three countries, the differences were similar for stunted and non-stunted children for both mild and moderate/severe anaemia.

When stratified by malaria status (middle portion of figure), the results show that children without malaria in Ghana had a 15 and 17 percentage point lower prevalence of mild and moderate/severe anaemia, respectively, in 2004. However, for children with malaria, there was no difference in the prevalence of mild anaemia but a nearly 25 percentage point lower prevalence of moderate/severe anaemia. In Malawi, a similar large percentage point lower prevalence of moderate/severe anaemia was observed among malaria positive children.

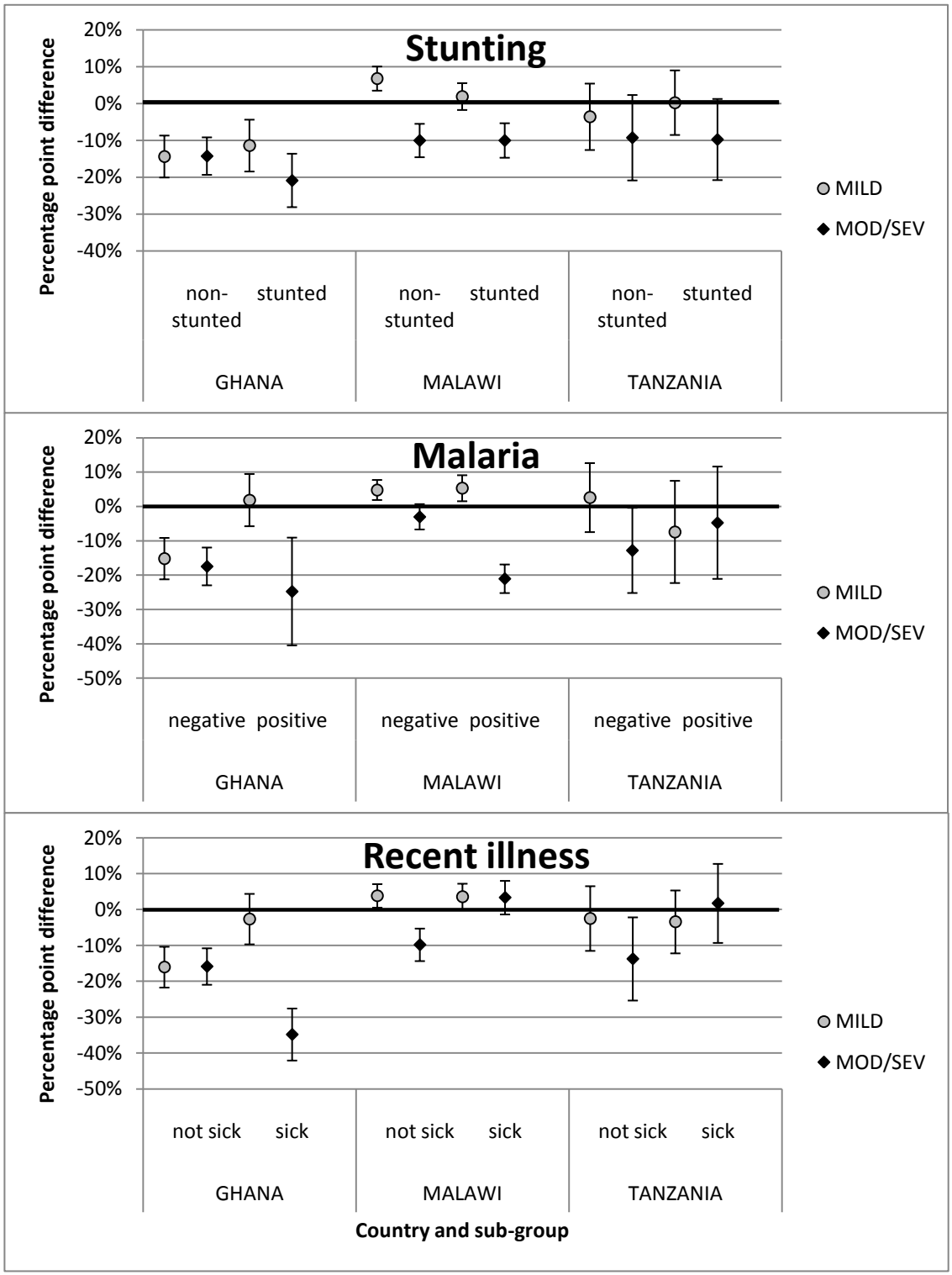



Figure 6.5: Percentage point difference in prevalence of mild and moderate/severe anaemia between 2000 and 2004 by country and child's stunting/malaria/illness status

Among the malaria subgroups in Tanzania, the only significant difference was observed among the malaria negative sub-group in which a 13 percentage point lower prevalence of moderate/severe anaemia was observed in 2004.

The results for comparison by recent illness status are shown in the bottom portion of the figure. A lower prevalence of moderate/severe anaemia is evident for children in Ghana in 2004 regardless of illness status, although the difference is much greater (35 percentage points) for children who were sick in the past two days than for those who were not (16 percentage points). Mild anaemia prevalence was similar across years for children who were sick whereas it was lower in 2004 for children who were not sick. In Malawi, the only recent illness subgroup with a lower prevalence in 2004 was children who were not ill and these children had a 10 percentage point lower prevalence of moderate/severe anaemia. In Tanzania in 2004, moderate/severe anaemia was 14 percentage points lower among children who were not ill but virtually the same as in 2004 among children who were ill. No differences in mild anaemia prevalence were observed for these two groups.

### 6.3.2 Population attributable risk

To assess the public health significance of stunting and morbidity on the prevalence of anaemia, population attributable risk (PAR) estimates were calculated for moderate/severe anaemia. Results of this analysis are presented in Table 6.8.

In Ghana and Malawi, the proportion of moderate/severe anaemia attributable to stunting was the highest of all the risk factors included in this analysis, ranging between 12 and 22 percent. In Ghana, the PAR for stunting appeared to be higher in 2004 (22.1%) than in 2000 (17.1%), despite a lower prevalence of stunting in 2004 (29.1% vs. 37.2% in 2000). In Malawi, stunting prevalence was similar at the two time points and the PAR associated with stunting appeared to be slightly higher in 2004 compared to 2000. In the Tanzanian context where a lower prevalence of stunting was observed in 2004 compared to 2000, the PAR for stunting was low at both time points.

Table 6.8: Population attributable risk of moderate/severe anaemia

| Risk Factor & Country | Year | Risk Factor Prevalence[1] | *pd*[2] | Adjusted RR[3] | PAR %[4] |
|---|---|---|---|---|---|
| **STUNTING** | | | | | |
| GHANA | 2000 (N=353) | 37.2 | 48.9 | 1.54 (1.13, 2.09) | 17.1 |
| | 2004 (N=296) | 29.1 | 45.3 | 1.95 (1.20, 3.18) | 22.1 |
| MALAWI | 2000 (N=466) | 57.7 | 62.9 | 1.23 (0.99, 1.53) | 11.7 |
| | 2004 (N=679) | 55.4 | 62.9 | 1.32 (1.06, 1.65) | 15.3 |
| TANZANIA | 2000 (N=634) | 65.5 | 66.7 | 1.08 (0.93, 1.26) | 5.1 |
| | 2004 (N=77) | 53.3 | 56.3 | 1.07 (0.57, 2.03) | 3.8 |
| **MALARIA** | | | | | |
| GHANA | 2000 (N=353) | 11.1 | 12.2 | 1.09 (0.68, 1.73) | 1.0 |
| | 2004 (N=296) | 7.6 | 7.6 | 0.71 (0.26, 1.97) | -[5] |
| MALAWI | 2000 (N=466) | 31.8 | 45.4 | 1.77 (1.43, 2.18) | 19.7 |
| | 2004 (N=679) | 13.4 | 16.3 | 1.26 (0.96, 1.65) | 3.4 |
| TANZANIA | 2000 (N=634) | 10.7 | 11.8 | 1.13 (0.91, 1.40) | 1.4 |
| | 2004 (N=77) | 18.2 | 21.9 | 1.64 (0.77, 3.49) | 8.5 |
| **RECENT ILLNESS** | | | | | |
| GHANA | 2000 (N=353) | 12.3 | 18.9 | 1.74 (1.18, 2.58) | 8.0 |
| | 2004 (N=296) | 12.5 | 17.0 | 1.49 (0.80, 2.79) | 5.6 |
| MALAWI | 2000 (N=466) | 29.8 | 33.0 | 1.17 (0.94, 1.47) | 4.9 |
| | 2004 (N=679) | 19.0 | 24.0 | 1.25 (0.98, 1.58) | 4.7 |
| TANZANIA | 2000 (N=634) | 54.1 | 57.8 | 1.13 (0.98, 1.31) | 6.7 |
| | 2004 (N=77) | 33.8 | 43.8 | 1.54 (0.81, 2.95) | 15.4 |

[1] Proportion of children exposed to risk factor; [2] *pd*=proportion of cases (children with Hb <100 g/L) exposed to risk factor;
[3] Adjusted RR = relative risk (incidence rate ratio) based on Poisson regression model with robust error variance, adjusted for age group, sex, stunting, malaria, recent illness, potable water, latrine type, wealth ranking, maternal education level and distance to health facility (and country for pooled model); [4] PAR = *pd*(Adj RR-1/Adj RR); [5] Estimate was less than 0 (negative number).

The measures of morbidity (malaria and recent illness) showed wider variation in PAR across countries between 2000 and 2004. In Malawi, 19.7% of moderate/severe anaemia cases were attributable to malaria in 2000, when prevalence of malaria was also high (31.8%). However, in 2004, the PAR for malaria in this context was much lower (3.4%), paralleling the observed lower malaria prevalence (13.4%). In Tanzania, the PAR for recent illness in 2004 was higher (15.4%) than that estimated for other countries and time points.

# CHAPTER 7: DISCUSSION

# 7 Discussion

## 7.1 Summary of key results

This study has shown that reductions in child anaemia were evident in areas benefiting from an integrated package of anaemia control activities and that these differences over a four-year period varied in magnitude and significance across country contexts. Documentation of differences in contexts, such as the underlying levels of child undernutrition and morbidity, as well as differences in health and nutrition intervention delivery and reach, provide some evidence for why this variability may have occurred.

In terms of risk factor analysis, the results of this study showed that stunting, malaria and recent illness were associated with the risk of anaemia but that these risk relationships differed across country contexts. Stunted children were at increased risk of anaemia in Ghana and Malawi, but not Tanzania. Overall, stunting was associated with a 3 g/L lower haemoglobin level, with no evidence for variation in this association between years. Malaria positive children were at increased risk of both mild and moderate/severe anaemia only in Malawi where prevalence of this risk factor was highest. A haemoglobin deficit of nearly 10 g/L associated with malaria in this context in 2000 was no longer evident in 2004. Recent illness increased the risk of moderate/severe anaemia among children in Malawi and showed a similar trend in Ghana and Tanzania. Associated with a lower haemoglobin of nearly 3 g/L overall, there was evidence in Ghana for a buffering of this relationship between the two time points.

Results also showed that children in the oldest age group continued to be at lower risk of moderate/severe anaemia, regardless of country or survey year. In fact, the magnitude of association with haemoglobin for age 48-59 mo (vs. 24-35 mo) was larger than for the three immediate causes (stunting, malaria, recent illness). Despite efforts in these areas to improve child health and nutrition from pre-conception onwards, it

appeared that any observed improvements in lifecycle health and nutrition were not associated with a change over time in the age-anaemia risk relationship.

Overall, little evidence was observed for a buffering effect of improvements in health and nutrition occurring among these children and their families between 2000 and 2004, in terms of reducing the negative impact of risk factors for anaemia. Although there were a couple of isolated examples of this, in general, improvements in anaemia levels appeared to be primarily attributable to decreases in the prevalence of risk factors. Lower anaemia prevalence, particularly moderate/severe anaemia, was more likely to be observed among children who were better off (e.g. non-stunted, no malaria), even when controlling for other underlying and basic causes. Based on PAR analysis, stunting accounted for the largest proportion of attributable risk in Ghana and Malawi.

## 7.2 Study limitations

This study was carried out using data collected as part of a NGO-implemented community-based health and nutrition program. It is not a program impact evaluation but rather it was explicitly designed to understand how anaemia outcomes evolved over time in the context of this type of program intervention. Therefore the limitations inherent in the data that are used in this study, while inconvenient in terms of hindering our ability to answer all the questions that may be asked, are viewed as an important reality within which one often must work. Working within this reality does not imply that program evaluations should not improve both in terms of quality and precision of measures assessed. However, it reveals what data may be available in these contexts and influences what can be learned about the differences that may be observed in anaemia and its risk factors between time points so as to inform future program efforts.

Although the package of nutrition and health interventions delivered in the study areas by the MICAH program is very similar to the current recommended list of effective interventions to reduce child undernutrition (Bhutta *et al.*, 2008a), and was also aligned with the context-specific causes of anaemia, one major limitation of this study is that the coverage achieved for each intervention varied widely and was often lower than expected. Furthermore, we were unable to estimate the extent to which each child

included in the study was reached with the various interventions delivered. Based on the coverage data summarized as part of the adequacy evaluation of the program (Table 5 in Berti *et al.*, 2010), coverage levels of around 70% or higher were achieved in all three countries for most anaemia-related interventions measured[23], with the exception of child ITN use in Ghana and Tanzania, and child iron supplementation and access to potable water sources in Tanzania. However, this did not include measures of coverage for dietary diversification strategies (including small animal husbandry, home gardening and dietary modification), infant and young child feeding education strategies, growth monitoring, deworming of children U5 and other specific disease control strategies (e.g. malaria treatment for children U5 with fever). For many of these strategies, the review of process indicators showed relatively low to moderate coverage of targeted groups in the program-targeted communities.

One assumption made in the statistical model building process is that there was no unmeasured confounding of the association with the outcome (whether anaemia status or haemoglobin level) of the various risk factors (exposures) at each level (Cole & Hernan, 2002). Based on the hierarchical structure of the theoretical framework used to guide the analysis, more distal risk factors, termed "basic causes" and "underlying causes", are expected to exert their effects on the outcome primarily through a number of inter-related more proximate risk factors (termed "immediate causes" in this analysis). Although no direct associations between the basic and underlying causes of anaemia are represented in the framework, residual associations for these risk factors with anaemia and haemoglobin were observed in our models. These residual effects are interpreted as associations not mediated through the more proximal risk factors included in the model. This underscores the fact that while the variables in our models may have been measured with a minimum of error, they still reflect imprecisely the constructs they are intended to represent. Stunting is an indicator of multiple constraints to health but does not reflect precisely the multiple dimensions of nutritional status, and malaria and recent illness are only two aspects of morbidity relevant to the study of child anaemia in these contexts.

[23] The list includes child vitamin A and iron supplementation, child use of ITN, immunization and household access to potable water and latrines.

The original plan of analysis was to test for variation by year in the risk of mild and moderate/severe anaemia associated with the independent variables, using the logistic regression models. However, since the datasets were insufficiently powered for this type of analysis, the analysis of change across years in these risk relationships was confined to use of the continuous dependent variable, haemoglobin level, in a linear regression model. Although this is a common methodology and allowed for useful comparisons with other studies in the literature, it limited our discussion to the variation by year in the risk of lower mean haemoglobin, which may be less programmatically useful than a discussion of change in the risk of anaemia.

The cross-sectional nature of the data did not allow us to ascertain causal relationships and therefore we cannot make any statement about what direction of effect occurred in the associations observed. Another major limiting factor was related to conducting *post hoc* analysis of data. This precluded data collection for variables of particular importance to the research questions being asked, such as measures of child iron status and dietary intake, inflammation, helminth infection, malaria parasite density, HIV status and genetic diseases known to be associated with anaemia (e.g. sickle cell anaemia). There was also inconsistency in the variables collected across years and between countries, despite program efforts to standardize data collection. This limited the number of variables that were able to be included in the models.

Although weighting of data collected using two-stage cluster sampling is recommended in order to account for different sampling probabilities, detailed sampling frames were not available for all country surveys and therefore it was not possible to calculate these weights. In reporting unweighted estimates of anaemia prevalence, it is likely that the standard error associated with these estimates has been underestimated since households within clusters are often similar to one another in their relevant characteristics (Deaton, 1997), but it has been shown that the household sampling scheme has little effect on variables representing nutritional status of children and their recent morbidity (Bennett *et al.*, 1994).

The fact that we excluded children with incomplete data may have introduced a certain amount of selection bias. Children without data for some variables may differ in

important ways from those with complete data and these characteristics may be associated with the risk of anaemia. Although the distribution and severity of anaemia was similar between study and excluded children with haemoglobin data, some other differences between the study and excluded samples were observed and therefore consideration of the impact on the internal and external validity of the results observed is warranted. The most consistent difference was related to the age distribution, as most of the study samples were more heavily weighted to younger children and this was associated, in turn, with the distribution of other key variables, notably measures of anthropometric status and morbidity. All analyses were adjusted for age to minimize the confounding effect of this characteristic.

Yet in the case of the Malawi data from 2000, the lower prevalence of malaria parasitaemia and higher prevalence of illness in the last two days among children in the study sample compared to excluded children were not associated with the age distribution. In this sample of children from across the country, regional variation in morbidity was evident (e.g. children from the northern region had significantly higher prevalence of illness in the last two days compared to children from the central and southern region, 31% vs. 21-23%, p=0.038), but it also did not explain the differences (i.e. children from the northern region were underrepresented in the study sample). The direction of the bias was not consistent (lower malaria but higher reported illness). And despite the differences in morbidity, there was no evidence for any difference in anaemia prevalence between study and excluded children. Therefore, the impact of this apparent bias on the internal validity of the study is unclear and interpretation of results for this sample should be undertaken cautiously. For the rest of the study samples, we believe that our results may be considered as having a reasonable level of internal validity.

Sample sizes were a further limitation; however, we expect to have sufficient power to detect medium effect sizes in most instances, with the exception of the Tanzania 2004 sample. It was most unfortunate that we were unable to include the baseline survey data and show trends from 1996/1997 onwards and also lacked adequate data for non-program areas in all three countries to provide evidence on secular trends

occurring independent of program intervention effects. It is not known what proportion of the children surveyed in 2000 and 2004 participated in the program or for how long. Given the moderate intensity of program activities in each community, it is inferred that most of the children surveyed had contact with at least some program activities (e.g., community meetings and home visits). However, coverage data were not available for all activities. These realities, along with others, limited our capacity to attribute any of our findings.

Due to the fact that the data were collected in the context of a community-based program evaluation and not a controlled trial, measurement error is expected to play a role in terms of the probability of finding statistically significant results. However, wherever possible, the characteristics of key measures were explored in different ways to try and ascertain the validity of these measures. In addition, measures of haemoglobin concentration and anthropometry have been documented to be highly reliable (Martorell & Ho, 1984). Finally, the overall quality of the MICAH survey data was assessed in a separate study and found to be of high quality (Berti *et al.*, 2010). Therefore we believe the results presented here have sufficient validity to be discussed in greater detail.

## 7.3 Evolution of anaemia

This study sought to characterize the evolution of anaemia and its risk factors among young children in areas of Ghana, Malawi and Tanzania benefiting from an integrated health and nutrition program designed to reduce anaemia.

The high prevalence of anaemia reported in 2000 for each country for children 24-59 mo is similar or slightly lower than the prevalence reported by other cross-sectional studies conducted in communities in rural areas within the past 15 years in the same regions of sub-Saharan Africa (see Appendix I). Although anaemia is often considered an acute condition, our results show that in 2000 the prevalence of anaemia exceeded 59% among children 24-59 mo, with moderate/severe anaemia ranging from 36% in Ghana to 42% in Malawi and 55% in Tanzania. This finding calls attention to the chronic nature of anaemia in these contexts and the persistent vulnerability of children in this older age group to its effects. Anaemia in these contexts is not a

temporary condition or a condition experienced only in the first two years of life but rather a chronic morbidity that manifests itself early in life and persists for years. A longitudinal study of haemoglobin levels among 942 Kenyan children showed that mean haemoglobin reached its lowest point of 92 g/L at the age of 9 months and remained well below the normal reference value for the duration of the 48 months that the children were monitored (McElroy *et al.*, 1999). The mean haemoglobin of children 24-59 mo in our study in 2000 was also well below the reference value, ranging from 97.0 g/L in Tanzania to 103.0 g/L in Malawi and 104.4 g/L in Ghana. These results support the design of anaemia control efforts that effectively address the main causes of anaemia not only among children under two years of age but also older children, where resources permit, as they continue to bear the consequences into later childhood.

Despite being situated in very different parts of the African continent, the profile of anaemia severity across countries was remarkably similar. The largest proportion of anaemia cases were classified as moderate in severity (Hb between 70 and 99 g/L). This is consistent with recent DHS survey results for the distribution of anaemia severity in each country (Ghana Statistical Service (GSS) *et al.*, 2004; National Bureau of Statistics Tanzania & ORC Macro, 2005; National Statistical Office (Malawi) & ORC Macro, 2005) and highlights the severity of the problem. The magnitude of moderate anaemia is likely due to the multiple factors involved in the aetiology of anaemia in these contexts and chronic exposure of children to them. Exposure to individual factors, such as iron and other micronutrient deficiencies or inflammation due to infection, is expected to increase the risk of mild anaemia (Thurnham & Northrop-Clewes, 2007). However, if iron stores are already depleted, if malaria parasites are not completely cleared from the blood, or if sub-clinical inflammation persists over a long period of time, moderate or severe anaemia inevitably develops and remains intractable. The added burden of HIV infection in these contexts may also be contributing to higher prevalence of both mild and moderate anaemia (Calis *et al.*, 2008; Shet *et al.*, 2009).

The low proportion of severe anaemia observed across time and in each country may be due in part to their similarity in terms of relatively low levels of malaria morbidity during the years studied and the expected lower vulnerability to clinical

malaria episodes among children in this older age group who have acquired resistance to malaria. The MICAH program interventions in all three countries provided regular hookworm treatment and iron supplementation for children U5 and this may have also played a role in keeping severe anaemia levels low. Finally, children with severe anaemia are at increased risk of death (Brabin *et al.*, 2001), and therefore this may result in a lower prevalence of severe anaemia in these contexts as well.

In terms of the differences observed in anaemia prevalence in these areas between 2000 and 2004, results showed two different patterns. In Ghana, the prevalence of overall, mild and moderate/severe anaemia decreased, as the shift to the right in the haemoglobin distribution was great enough to see significant improvements at all cut-off levels. However, in Malawi and Tanzania, the differences observed between 2000 and 2004 were smaller in magnitude and as a result, significant improvements were seen at some cut-offs but not others. In Malawi, although the prevalence of moderate anaemia was 8.5 percentage points lower in 2004 ($p=0.004$), this was offset by a slightly higher prevalence in mild anaemia and so the overall difference in anaemia (5.1 percentage points lower in 2004 compared to 2000) was not statistically different from zero. In Tanzania, the difference in overall anaemia between 2000 and 2004 was larger (12.3 percentage points lower in 2004) and statistically significant ($p=0.02$) while differences in mild and moderate/severe anaemia showed a similar pattern to Malawi but were not statistically different from zero. These differences across time in distribution of anaemia severity are important aspects to consider in the design and interpretation of anaemia control program evaluations. Assessing the change over time in anaemia using multiple cut-off points provides insight into changes that may be occurring at lower levels of the haemoglobin distribution without having an effect on overall anaemia (Stoltzfus, 1997). A program that results in a movement of a proportion of the population from moderate to mild anaemia status may be considered a successful program, even if the overall prevalence of anaemia does not change as a result.

The dramatically lower prevalence of anaemia observed among children 24-59 mo in the Ghana sample in 2004 compared to 2000 was also substantially lower than any other survey finding in that country for children U5, even one conducted in an urban

area where anaemia tends to be lower (Klinkenberg *et al.*, 2006). This 52% reduction in anaemia over a four-year period was larger than could be expected due to secular trends and falls within the range of reported changes in child anaemia reported in the literature to date by large scale programs at the community level. Menon et al. (2007b) reported a 74% reduction in anaemia (from 54 to 14%) among younger children (9-24 mo) in Haiti. Lechtig et al. (2009) reported a 31% reduction in the prevalence of anaemia between 2000 and 2004 among children less than three years of age in Peru. A recent estimate of the reduction in anaemia achieved with iron supplementation alone ranged from 6-32% in malarial hyperendemic areas and 38-62% in non-malarial areas (Bhutta *et al.*, 2008b).

What is even more striking is that the observed decrease in anaemia in Ghana occurred with only modest changes in the same period of time in the prevalence of immediate, underlying or basic causes of anaemia measured by the program evaluation survey. In fact, the differences observed between 2000 and 2004 in indicators of child health and nutritional status, household health and nutrition practices and family socioeconomic indicators were not that different between Ghana and Malawi. In many aspects, the indicators showed a similar or better status of Malawian children in 2004 compared to children in Ghana, with only a few exceptions (e.g. higher stunting, lower maternal education levels, and poorer housing materials in Malawi). This suggests that there are key indicators related to anaemia control that were not measured by the program and that could help to explain this difference.

The role that iron deficiency played in each of the three contexts is unknown but is likely to be an important explanatory factor in terms of understanding the observed differences between time points in anaemia prevalence. Stoltzfus et al. (2004b) estimated that iron deficiency is responsible for approximately 50% of anaemia globally and elimination of iron deficiency where anaemia is prevalent would result in an increase in mean haemoglobin of at least 11.7 g/L. In our study, mean haemoglobin increased by 8.7 g/L in Ghana, 5.2 g/L in Tanzania and 2.7 g/L in Malawi. However, the fraction of anaemic children that were iron-deficient and the fraction that were iron-responsive may have been very different across the three country program areas (Solomons, 2002). Iron deficiency may be more prevalent and more difficult to address

among young children in Malawi and Tanzania than in Ghana, given the higher levels of phytate and other iron absorption inhibitors in the diet in these countries (Ferguson *et al.*, 1993). Despite the fact that both Ghana and Malawi programs achieved high iron supplementation coverage among children U5, Malawian children may have been less able to effectively absorb and utilize the added iron. Differences in compliance may also have played a role, despite the fact that program monitoring records showed high levels of reported compliance with iron supplementation for young children in both countries (World Vision Canada, 2006a; 2006b). Although child morbidity was lower in 2004 compared to 2000 in Malawi, chronic inflammation may have also reduced iron responsiveness to a greater degree than in Ghana or Tanzania. Higher levels of stunting observed in Malawi and Tanzania also likely resulted in a blunted response to the nutrition and health interventions, as other micronutrients and macronutrients may be insufficient in the diet (Allen *et al.*, 2000; Ouedraogo *et al.*, 2008). Finally, other context-specific factors, such as the recent national drought in Malawi and higher levels of HIV infection among children in Malawi and Tanzania may have hindered greater changes in the prevalence of anaemia in these contexts (MacDonald *et al.*, 2007; Stuckler *et al.*, 2010).

Regional variation in the differences observed between 2000 and 2004 in anaemia in Malawi was also evident. Although the anaemia profile of children included in our study was very similar across regions in 2000, only children in project areas from the northern region of the country showed significantly lower anaemia levels in 2004. While a smaller and non-significant difference was observed among children in the central region, anaemia levels showed a tendency to be higher among children from the southern region in 2004 compared to 2000 (70.5% vs. 62.0%, respectively; p=0.057). These variations correspond with documented regional differences in population density, educational attainment, literacy, food insecurity and child mortality in this country (Malawi National Statistical Office & International Food Policy Research Institute, 2002; Malawi National Vulnerability Assessment Committee, 2005; Makoka, 2009), suggesting a relative socioeconomic advantage in the northern region compared to the other two regions and calling attention to the powerful influence of these wider social determinants of health. This is consistent with the perspective taken by Link and

Phelan (1995) in their description of social conditions as "fundamental causes" of disease. In their work, they suggest that interventions that address individual-based mechanisms linking these fundamental causes to disease outcomes will not be successful unless they also intervene in ways that directly change the social conditions themselves. Regional differences may also be associated to some degree with differences in MICAH program intervention by partners and supervision by program coordinators.

Regardless, the trends in anaemia prevalence observed in these countries are not unusual and other community-based program evaluations have also reported difficulty in reducing child anaemia levels, both in the sub-Saharan African context and elsewhere. A recent review of conditional cash transfer program evaluations in Latin America found that only one of three programs that evaluated impact on anaemia was successful in improving haemoglobin levels and reducing anaemia (Leroy *et al.*, 2009). The authors suggested that the limited impact of the programs on anaemia was likely due to problems with program design and poor utilization of the micronutrient interventions provided. IMCI was expected to contribute to a reduction in anaemia in young children through improving health worker skills, strengthening health systems which support IMCI and improving family and community practices which support child health and survival. However, the effect of the IMCI strategy on child anaemia levels, as assessed in Tanzania, was not different from other programs offered in the country, as the comparison of anaemia in children 6-59 mo between two IMCI-implementing districts with two control districts showed relatively equal improvement in anaemia prevalence over time (MCE, 2003). Despite the use of multiple and integrated interventions, child anaemia has proven difficult to reduce in program (non-research) settings in developing countries.

## 7.4 Risk factors for mild and moderate/severe anaemia

In order to build on existing knowledge of risk factors for child anaemia, this study was interested in identifying the risk factors for mild and moderate/severe anaemia

across three African country contexts. In addition, for the immediate causes, the analysis sought to determine whether these risk relationships differed between 2000 and 2004.

### 7.4.1 Mild vs. moderate/severe anaemia

The reasons for assessing risk factors for mild vs. moderate/severe anaemia in this study are two-fold: 1) to determine whether mild anaemia may be associated with different factors than those associated with more severe anaemia, in which case different strategies should be adopted in order to reduce it; and 2) to determine for the risk factors in common whether there may be a difference in the strength of association. Results of this analysis showed that mild anaemia risk was poorly explained by most of the variables included in the models. Only two risk factors were significantly associated with mild anaemia. Children from households reporting the use of the bush as their toilet facility were at increased risk of mild but not moderate/severe anaemia in the Ghana model. In the Malawi model, malaria parasitaemia was associated with both mild and moderate/severe anaemia and there was evidence for a stronger association with more severe anaemia.

The general lack of evidence for unique risk factors for mild anaemia may be indicative of the nonspecific nature of this type of morbidity. Children in these contexts may regularly shift between normal and mild anaemia status, given the limited food sources of iron and frequent infection rates. Alternatively, using the haemoglobin concentration range of 100-109 g/L may in fact be erroneously classifying these children as mildly anaemic when in reality they have functionally and biologically normal haemoglobin levels. Studies have observed lower haemoglobin levels among children of African descent in comparison to non-Hispanic white children in the USA (Robins & Blum, 2007) and Western European comparator populations (Humberg *et al.*, 2011). The evolutionary perspective suggests that the prevalent iron deficiency observed in African populations is an adaptive response to environments with high levels of infectious disease (Denic & Agarwal, 2007) and therefore may be regarded as protective.

The lack of mild anaemia-specific risk factors is also very likely due to inadequate statistical power in this study (the majority of anaemic children had more severe anaemia) and the fact that the selection of variables to be included in the multivariate models was limited to those that were available for all countries and both years. This resulted in the omission of some variables collected by the program that were expected to be associated with mild anaemia (e.g. child meat intake, child iron supplement access, vitamin A supplement status, maternal knowledge of anaemia prevention). However, several of these variables were explored at the univariate level of analysis in specific countries and the results of this analysis also showed little explanatory power in terms of mild anaemia.

For moderate/severe anaemia, however, there were several risk factors identified, including child stunting, malaria parasitaemia, recent illness, proximity to health facility and age group. Sensitivity analyses showed that the strength of association was attenuated when overall anaemia was modeled instead of mild and moderate/severe anaemia (data not shown), suggesting that the cut-off used is important. Given the evidence for important health and development consequences of more severe anaemia, this study confirms that anaemia risk factor analysis should not be limited to overall anaemia in young children (Ngnie-Teta *et al.*, 2007). In addition, research in this area would be greatly enhanced by the development of a reference curve for haemoglobin that is appropriate for use with African populations, including cut-offs for anaemia severity.

### 7.4.2 Evidence for reduced child vulnerability

Our theoretical framework and concept of child vulnerability predicted that young children living in areas benefiting from a package of integrated health and nutrition interventions would become less vulnerable over time to the negative impact associated with known risk factors for anaemia. Based on the hierarchical nature of the model, the effects of basic and underlying causes of anaemia were expected to be fully mediated through the immediate causes, namely undernutrition and morbidity. The following paragraphs discuss the evidence to support this conceptualization of these risk relationships.

#### 7.4.2.1 Undernutrition

Stunting, used in our models as a proxy for undernutrition, was largely present in all countries but was an important independent risk factor for moderate/severe anaemia in only two of the three countries. Stunting was associated with a 3 g/L lower haemoglobin level in the pooled dataset, with no evidence for variation in this association by year. These results are consistent with the majority of other cross-sectional studies from similar areas and age groups that have also shown an increased risk of anaemia and lower mean haemoglobin levels associated with stunting (Schellenberg *et al.*, 2003; Desai *et al.*, 2005; Drakeley *et al.*, 2005; Friedman *et al.*, 2005b; Ngnie-Teta *et al.*, 2007). However, in one study from Ghana, underweight but not stunting was associated with an increased risk of anaemia (Ehrhardt *et al.*, 2006) and in a study from Tanzania, where 84% of children 6-59 mo were anaemic and 57% were stunted, only iron deficiency was associated with an increased risk of anaemia (Tatala *et al.*, 1998).

Remarkably, in Tanzania, there was no statistically significant increased risk of anaemia for stunted children at either time point, despite the fact that 66% of children in this context were stunted in 2000 and a significant decrease in stunting prevalence was observed over time. The highest risk of moderate/severe anaemia associated with stunting was observed in Ghana, the country with the lowest prevalence of stunting. Although Malawi's stunting levels were more similar to Tanzania and showed no significant reduction between 2000 and 2004, stunting was associated with moderate/severe anaemia in this context. Results from the PAR analysis were consistent with these inter-country patterns: about one fifth of moderate/severe anaemia was attributable to stunting in Ghana, slightly less in Malawi and very little in Tanzania.

The reasons for this pattern of results across countries are not clear. While anthropometric data are very useful as a measure of malnutrition, they are also sensitive to many factors (essential nutrients, infection, climate, stress and genetics) and can only indicate that there is a problem, not revealing what are its causes (Martorell & Ho, 1984; Branca & Ferrari, 2002).

One possible explanation is that stunting is an indicator of extreme vulnerability. In contexts such as the Ghana program area, where stunting levels are moderate, as fewer children become stunted due to gradual improvements in nutrition and health over time in a population, those who are still stunted represent the most poor and undernourished children in the community. In contexts where the majority of children are stunted, as in Tanzania, the risk of anaemia may be more equal across stunted and non-stunted children.

Another possible explanation is that in the Ghana program areas, iron deficiency was effectively addressed through consistent and widespread iron supplementation of children 6-59 mo. While this resulted in a reduction in anaemia levels, iron was not the key limiting nutrient in terms of linear growth retardation, as measured by stunting, and therefore no change in the risk of anaemia associated with stunting was observed. Perhaps there is another key limiting nutrient that contributed to persistent stunting and increased risk of anaemia. One potential candidate for this nutrient is zinc. Ferguson et al. (1993) proposed that differences in zinc nutriture may have contributed to the higher prevalence of stunting observed in Malawi compared to Ghana in their study, since energy and protein intakes did not explain it. A similar explanation may apply in Tanzania, given the similarities in diet to Malawi.

Results also suggest that while undernutrition plays an important role in the whole spectrum of anaemia severity, children who are stunted are particularly at risk for more severe anaemia. Although the risk of mild anaemia associated with stunting was not statistically significant in any of the countries, there was evidence in both Ghana and Malawi of a tendency for increased risk but at a lower level than for moderate/severe anaemia. This finding is supported by other studies showing more severe anaemia associated with infections among stunted children (Guyatt *et al.*, 2001; Verhoef *et al.*, 2002).

The fact that there was no variation between 2000 and 2004 in the risk of lower haemoglobin levels associated with stunting in any of the three country contexts was unexpected, given the interventions that were being delivered in these communities. Improvements in child health and nutrition, increases in household food diversity,

maternal knowledge of appropriate child care and feeding practices, as well as improvements in health care services and healthy environments were expected to contribute to enhanced child capacity to respond. However, the vulnerability to anaemia associated with stunting remained unchanged.

No studies that we are aware of have looked at the change over time in the relationship between haemoglobin and stunting. In one longitudinal study of Kenyan children from birth to 4 y, weight-for-age was included as a time-varying covariate and results found that children with elevated weight-for-age ($90^{th}$ percentile) had a higher mean haemoglobin level than children with normal or low weight-for-age at the same age and that this effect appeared to be strongest after 24 mo, suggesting decreased vulnerability (McElroy *et al.*, 1999).

#### 7.4.2.2 Morbidity

In terms of child morbidity, we hypothesized that the risk of mild and moderate/severe anaemia associated with morbidity would be lower in 2004 compared to 2000. The following sections discuss the findings related to the risk associated with malaria and recent illness, the two indicators of morbidity included in the analysis.

##### *7.4.2.2.1 Malaria*

Malaria is a major contributor to anaemia, especially moderate and severe anaemia, in young children in Africa. Malaria infection can have a direct effect on a child's haematological status and the full consequences of malaria may be modified by several factors, including the child's nutritional status (especially iron status) before, during and after any clinical episode, the promptness and effectiveness of the treatment and the time for recovery prior to the next episode (Ekvall, 2003). Due to the MICAH program and other national Roll Back Malaria program efforts during the period of 2000 to 2004 to increase coverage for malaria prevention practices (e.g. use of insecticide-treated nets) and improve effectiveness of care-seeking practices and treatment of malaria cases, a reduction over time in both the prevalence of malaria and its negative impact on child health and nutritional status was expected. Thus, we hypothesized that in addition to a lower prevalence of malaria among the children in our samples in 2004,

the association of malaria parasitaemia with lower haemoglobin levels would also decrease in magnitude between 2000 and 2004.

The relationship observed between anaemia and malaria in the Malawi samples was consistent with our hypothesis. In this context, malaria was associated with the risk of both mild and moderate/severe anaemia. The prevalence of malaria parasitaemia was moderately high in Malawi in 2000 (31.8%) and children with malaria had much lower mean haemoglobin levels (-9.81 g/L) compared to those without malaria. But in 2004, malaria prevalence was lower (13.4%) and its risk relationship to haemoglobin was attenuated; children with malaria had a mean haemoglobin level similar to children without malaria. The lower PAR for malaria in 2004 compared to 2000 in Malawi also suggests that malaria is a less important contributor to the problem of moderate/severe anaemia in 2004. These results from Malawi provide support to our hypothesis that the improvements in health and nutrition occurring among children and their families between 2000 and 2004 may have provided a buffering effect, contributing to a decrease in children's vulnerability to the anaemia-producing effects of malaria, despite the ongoing presence of this disease in their area. The reduction in magnitude of the lower haemoglobin associated with malaria between 2000 and 2004 may be due to the reduction in exposure to malaria during this time period, the expected buffering effect of other interventions, or a combination of these.

Improved child nutrition may have been one contributor to reduced malaria-associated morbidity. A positive difference in nutritional status, namely a lower prevalence of underweight in 2004, was evident among children from Malawi. However, no difference in stunting was observed. Results from the PAR analysis for this country's samples suggest that as the risk of moderate/severe anaemia attributable to malaria became lower in 2004, that attributable to stunting became higher.

Child iron status was not directly measured in our study but may have improved due to the fact that almost three-quarters of the children surveyed were benefiting from iron supplementation in 2004. In light of conflicting evidence from research on the relationship between iron and malaria (Prentice *et al.*, 2007a), it is unclear whether the community-based universal distribution of iron supplements to children U5 in these

areas was beneficial or not in terms of malaria-associated morbidity, including malarial anaemia. In the data available in 2004, there was no association between reported access to weekly iron supplementation for a child U5 in the household and the child's anaemia or malaria status. Although the inflammatory response during acute malaria episodes blocks iron absorption and utilization, it is not known whether chronic low-density asymptomatic parasitaemia also limits a child's response to supplemental iron (Prentice *et al.*, 2007b). A large trial in Zanzibar found an increased risk of adverse effects associated with iron and folic acid supplementation in children 1-35 mo, but a substudy of the same trial reported that children who were iron deficient or anaemic at baseline experienced significant benefits from IFA supplementation relative to their placebo-supplemented peers (Sazawal *et al.*, 2006; Stoltzfus *et al.*, 2007). Since a large proportion (almost 60%) of preschool children in Malawi have iron deficiency anaemia (National Micronutrient Survey in Malawi, 2001), universal iron supplementation may have contributed to improved iron status in most children in this study, resulting in a decrease over time in the haemoglobin deficit associated with malaria, especially chronic malarial infection.

Increased availability of malaria treatment at the community level also may have contributed to a lower severity of malaria-associated morbidity, as found in other studies in Africa (Delacollette *et al.*, 1996; Sirima *et al.*, 2003). A recent household survey in Blantyre District in Malawi found that children living in rural locations were less likely to receive prompt, appropriate treatment for fever illness (Holtz *et al.*, 2003). To improve access to prompt and appropriate treatment for malaria, the MICAH program established village health revolving funds and trained community health volunteers in the provision of basic medicines for common illnesses, including the provision of malaria treatment. Community health education sessions also focused on malaria as an important cause of malnutrition in young children and the importance of prompt and effective care-seeking behaviours. These interventions may have been contributing factors to the decrease in severity of anaemia associated with malaria, as caregivers for sick children in more remote communities understood the importance of prompt treatment and were able to access appropriate medicines more easily. Although the reach and coverage for these interventions is not known for the children included in this

analysis, the MICAH Malawi 2004 survey results showed a significantly higher proportion of children U5 in MICAH program areas compared to non-program areas who had malaria in the two weeks preceding the survey and received malaria treatment (66% vs. 45%, $p<0.05$) (World Vision Canada, 2006b). Survey results also reported a higher proportion of respondents in MICAH areas correctly cited the signs and symptoms of malaria.

The program may have also successfully reduced co-infection rates through deworming and water, sanitation and hygiene promotion activities. Concurrent helminthic infections make the immune response to malaria more inflammatory in young children (Haldar & Mohandas, 2009). A reduction in levels of co-infection may lessen the severity of the inflammatory response to malaria in children and lower negative impact on haemoglobin levels. Although data were not available on individual child hookworm infection status or time since most recent deworming medicine received, the program supported mass deworming of all children 2-5 y every six months. A reduction in child illness, as evidenced by a decrease over time in the proportion of children who were sick in the two days preceding the survey, also likely contributed to improved health and nutrition of children, enhancing their capacity to respond to malaria infection.

The relatively low and stable prevalence of malaria parasitaemia observed over time in Ghana and Tanzania, as well as the lack of association between malaria parasitaemia and risk of mild or moderate/severe anaemia in univariate or multivariate analyses, contrasts with data from most other studies in Africa. Although several studies showing a strong association between malaria parasitaemia and anaemia also had a higher prevalence of parasitaemia than that found in our study (Premji *et al.*, 1995; Bloland *et al.*, 1999; Desai *et al.*, 2005), an increased risk of anaemia has also been documented in areas where only 13 to 40% of children have malaria parasitaemia (Cornet *et al.*, 1998; Brooker *et al.*, 1999; Lusingu *et al.*, 2004; Ronald *et al.*, 2006). Nevertheless, two other studies conducted among children 24-59 mo in African malaria-endemic contexts failed to find an association. Stoltzfus et al. (2000) found that the haemoglobin deficit associated with parasitaemia decreased with age among children

from Pemba Island, Tanzania, and was absent in children over 30 mo of age, even though malaria parasitaemia was found in over 75% of the overall sample. And in a mainland Tanzanian context where 34% of the children were malaria positive, Tatala et al. (1998) found no correlation between malaria status and anaemia among children 6 mo to 5 y.

Although studies in both Ghana and Tanzania have found that individuals, including children 24-59 mo, with asymptomatic low density parasitaemia were at a lower risk of developing a febrile malaria episode compared to children without detectable parasitaemia or with higher levels of parasitaemia, these children were still at markedly higher risk of developing anaemia. In the study from Tanzania, the risk of developing anaemia was 4.4 times higher (95% CI 1.10, 17.69; p=0.038) in individuals with low-density parasitaemia than in those who were slide negative (Lusingu *et al.*, 2004). In Ghana, fewer children 1-11 y of age with asymptomatic preseason infections subsequently developed malaria than children without detectable preseason parasitaemia (relative risk of acquiring malaria 0.75; 95% CI 0.57, 1.00; p=0.04), suggesting that asymptomatic infection can protect against subsequent clinical attacks in semi-immune children (Ofori *et al.*, 2002).

One possible explanation for the low prevalence of malaria and lack of association with risk of anaemia in study areas of Ghana and Tanzania may be that malaria control efforts have been successful in these areas before and during the time of our study. A recent study from north-eastern Tanzania showed a marked decline in malaria morbidity between 2003 and 2008 (Mmbando *et al.*, 2010). However, although malaria control interventions were being implemented in these areas, based on the data available during the period under study, coverage for proven malaria prevention practices remained relatively low. Ownership of mosquito nets by households was estimated to be less than 10% in Ghana and 34% in Tanzania in the year 2000 and these levels increased to 35% and 63% in 2004, respectively. However, net ownership was not associated with malaria status in Tanzania in either year and was inversely associated with malaria status in Ghana in 2004 (children from households that owned a net had a

higher prevalence of malaria, 15.5 vs. 4.1%, $p<0.001$), suggesting that households with higher malaria morbidity self-selected to use mosquito nets.

Other possible reasons for a lower than expected malaria prevalence may be measurement error and the seasonality of malaria transmission in these areas. Although the measurement of malaria parasitaemia was done using an internationally recognized method in all three countries, no information was available on quality assurance, such as duplicate slide readings. Lack of parasite density data also limited the sensitivity of this measure. Given the older age of the children in this study, many infections may have been of low-density and therefore more difficult to detect. Kitua et al. (1997) found that packed cell volume levels among infants in Tanzania were related to historical as well as concurrent parasitaemia. This suggests that current haemoglobin levels could be influenced by parasitaemia in the previous month, even if not currently infected.

Nonetheless, each survey was conducted at the same time of year as previous surveys in both countries and the time of year (September in Ghana, December/January in Tanzania) was associated with increased malaria transmission in the program areas, although perhaps not the peak. In Tanga region of Tanzania, malaria transmission is determined by altitude and large differences in transmission are found within a limited geographical area. Malaria transmission season peaks just after the rainy seasons (short rains from November to December, long rains from April to May) with most consistent transmission in lowland sites from April to July (Lusingu *et al.*, 2004). In Ghana program areas, malaria transmission is perennial, with seasonal variation and peak transmission during and after the rainy season (May to October) (Gardiner *et al.*, 1984). The degree to which inter-annual variation in climate and vulnerability affected malaria-associated morbidity in these areas is also not known (Thomson *et al.*, 2004).

Finally, there truly may be no increased risk of anaemia associated with malaria in these children. Consistent with the results of the PAR analysis, other factors such as undernutrition, including iron deficiency, and other infections may play a more important role in the aetiology of anaemia among children 24-59 mo in these contexts. This would be consistent with the findings of other studies as well (Tatala *et al.*, 1998; Stoltzfus *et al.*, 2000).

*7.4.2.2.2 Recent illness*

There was evidence for an increased risk of moderate/severe but not mild anaemia among children who were sick in the previous two days in all three country contexts in our study; the association was strongest in Malawi but a similar trend was observed in Ghana and Tanzania. Overall, children with a recent illness had a lower mean haemoglobin level of almost 3 g/L, a magnitude similar to that for stunting. Children who were ill were expected to be at increased risk of anaemia, given what is known about the effect of inflammation on the body's iron metabolism and erythropoeisis. Although the anaemia of inflammation is commonly short-term and of a mild severity (Thurnham & Northrop-Clewes, 2007), it can be associated with more severe and chronic anaemia in contexts of widespread iron deficiency, frequent illness and high levels of stunting.

The lack of association with mild anaemia observed in our study may be due in part to the lack of precision and sensitivity of this measure. In the MICAH surveys, recent illness was assessed based on caregiver perceived and reported illness in the two days prior to the survey. It is likely that a child's illness would need to be of sufficient severity for the caregiver to notice and report it in the interview, thus increasing the likelihood of its association with more severe anaemia (Schellenberg *et al.*, 2003). The recall period of two days includes children who became ill in the hours prior to the interview as well as children who may have been sick for two weeks, resulting in low sensitivity to length of illness which in turn is related to the degree of inflammation present and its effects on other outcomes, including haemoglobin concentration (Thurnham *et al.*, 2010). Based on data available only for 2004, the proportion of children reported sick in the last two days that were also sick in the last two weeks ranged from 29% to 57% across the three countries. Although there is bias due to disparity in the definition of illness for each caregiver, the specificity of the two-day measure was relatively high in all countries: 80-90% of children not sick in the previous two days were also not sick in the previous two weeks in the 2004 samples. Data on type of illness reported by the caregiver were inconsistently available and therefore not included in the analysis. However, among children whose type of illness was recorded,

this measure included a wide variety of ailments, ranging from the commonly reported types of fever, diarrhoea and cough to more rare types such as skin rashes. The majority were categorized as fever (59%) but less than one third of those tested positive for malaria parasitaemia. Direct measures of recent diarrhoea episodes, respiratory infections and helminthic infections were not available for all three countries.

Despite these limitations of the measure of recent illness used in this study, the strength of association with anaemia observed in Malawi (RR 1.28; 95% CI 1.05, 1.51) is similar to other studies in sub-Saharan African countries that quantified the risk of moderate/severe anaemia associated with illness in the past two weeks (Schellenberg *et al.*, 2003) and diarrhoea in the past two weeks (Ngnie-Teta *et al.*, 2007; Custodio *et al.*, 2008). Studies from other regions have also found an increased risk of anaemia associated with recent diarrhoea, fever or cough among children U5 (Hassan *et al.*, 1997; Howard *et al.*, 2007; Semba *et al.*, 2008). In the pooled sample in our study, the magnitude of association (approximately 3 g/L) is also in line with that observed in other cross-sectional studies. In a study in Kenya among children 0-36 mo, a model that included malaria parasitaemia (as our model did) showed a decrease in mean haemoglobin of 3.1 g/L for children with diarrhoea in the last two weeks, 6.4 g/L for fever in the last two weeks and 7.9 g/L for current fever (Desai *et al.*, 2005). Two studies from other regions also reported a decrease in mean haemoglobin of 2.1 g/L among children with diarrhoea in the previous two weeks (Osorio *et al.*, 2004; Agho *et al.*, 2008).

This risk relationship occurred despite the inclusion in the model of water and sanitation indicators, which may be associated with a child's risk of diarrheal diseases and other parasitic infections. In Ghana, the risk relationship between anaemia and recent illness was attenuated when variables related to the household socioeconomic status and proximity to health facility were added to the model. Proximity to a health facility particularly had an attenuating effect in this context, which may be an indication of the role of health care-seeking behaviours in the risk of anaemia associated with child illness.

Contrary to expectation, there was only evidence found in one country in our study for a change in the risk of lower mean haemoglobin associated with recent illness. Results from Ghana suggest there was a buffering between 2000 and 2004 of the association of illness with mean haemoglobin in the areas surveyed, since children with recent illness were less negatively affected in terms of their Hb level in 2004 compared to 2000. The PAR for recent illness also showed a trend in a lower direction, despite the fact that the prevalence of illness remained the same between 2000 and 2004. This suggests that while children living in these areas were still experiencing a similar level of common illnesses, they may have been responding differently to that exposure due to improved immunity and nutritional status and improved sick child caring practices (including increased health service utilization).

One possible reason for no evidence for change in this risk relationship in Malawi and Tanzania is that there were insufficient changes to the factors that mitigate a child's vulnerability to the effects of common illnesses. However, a significant decrease over time was observed in the proportion of children recently ill in Malawi and Tanzania, suggesting that there was reduced exposure and improved disease control in these areas in 2004 as compared to 2000. Reduced exposure may have been achieved through improved personal and food hygiene, potable water source access and cleaner environments, all areas of program education efforts. It cannot be confirmed whether these resulted in observable changes, since household access to potable water sources and use of sanitary toilet facilities did not change markedly for children included in this study. Improved disease control was very likely to have been achieved through universal deworming of children 2-5 y every six months in Ghana and Malawi and treatment of preschool children in Tanzania through routine health services and mobile units. Based on a meta-analysis of the effect of anthelminthic drugs on haemoglobin, the average estimated reduction in prevalence of anaemia in children (using 110 g/L cut-off) associated with this particular illness ranged from 4 to 21% (Gulani *et al.*, 2007).

Improvements in child immunocompetence and nutritional status were also expected to decrease child vulnerability to the negative effects of illnesses. Improving the nutritional status of children lowers morbidity and mortality and improves growth

impaired by infection (Scrimshaw, 2003). Some improvement in child nutritional status was evident in program areas of all three countries, with lower levels of stunting in Ghana and Tanzania and fewer underweight children in Malawi in 2004 compared to 2000. In addition, micronutrient status was expected to have improved in all three countries due to increased coverage for vitamin A and iron supplementation strategies as well as the unmeasured effects of promoting the increased production and consumption of micronutrient-rich foods. Vitamin A and iron both play an important role in child immunity and improved vitamin A status has been shown to improve iron metabolism (Semba & Bloem, 2002). Vitamin A supplementation in young children has been shown to reduce the severity of measles morbidity and decrease the severity of some diarrheal episodes in childhood and their incidence when administered in combination with zinc (Villamor & Fawzi, 2005). The effects of iron supplementation on morbidity include the potential to decrease infectious morbidity by correcting immune defects due to iron deficiency and the risk of increasing morbidity through increased iron available to pathogens (Stoltzfus *et al.*, 2007).

Given the high levels of stunting in the program areas included in this study, it is likely that these children were suffering from multiple nutritional deficiencies that limit immunocompetence. There is also growing evidence that stunted children respond in different ways than non-stunted children to interventions such as vitamin A supplementation. A study in Panama found that the duration of benefit from combined vitamin A supplementation and deworming was less in stunted children (Payne *et al.*, 2007). In the Philippines, improved retinol levels persisted for a much shorter time among stunted compared to non-stunted children (Pedro *et al.*, 2004). These results suggest that the level of buffering that health and nutrition interventions have on child vulnerability may vary based on the factors underlying child stunting and this may help to explain why little buffering of MICAH program interventions was observed in terms of decreasing the risk of anaemia associated with recent illness in Malawi and Tanzania.

Another possible reason for observing a change in this risk relationship only in one context is that the inflammation associated with infections in these children is unavoidable, no matter what is the child's capacity to respond. In this case, program

interventions can only hope to reduce exposure to pathogens and improve case management to ensure rapid recovery of haemoglobin levels, rather than expect to avoid the inflammation-associated decline in haemoglobin during illness. The inflammatory response (acute phase response) that is triggered following an external or internal inflammatory stimulus is a normal function of the body's innate immune system and plasma concentrations of several nutrients, including iron, fall rapidly, irrespective of nutritional status (Thurnham & Northrop-Clewes, 2007). This decrease in nutrient availability may have more serious functional consequences for children with prolonged infection and those who were already malnourished at the outset, including a reduced ability to deal with the infection. However, there is general consensus that the mild anaemia associated with an inflammatory response may be beneficial or protective, particularly for children living in areas with high exposure to infection (Ratledge, 2007; Stoltzfus *et al.*, 2007; Thurnham & Northrop-Clewes, 2007). Further elucidation of these mechanisms and their relevance in contexts with high levels of child malnutrition and frequent illness is needed.

#### 7.4.2.3 Underlying causes

Underlying causes of anaemia that contribute to malnutrition and morbidity include food security, child care practices, access to health care services and a healthy environment. It is at this level that the majority of program interventions acted directly. Therefore, in our analysis, we sought to include indicators of these factors. Unfortunately, there were many potential indicators[24] that were not collected at both time points or in all three countries, limiting the degree to which the hypothesis related to this level of the conceptual framework could be tested.

In terms of food security, indicators of child intake of animal source foods, and household production and consumption of animal products were initially examined. There was very little evidence at the bivariate level in any of the countries and at both

[24] Indicators for which data were collected by some but not all surveys included child meat/fish consumption, household use of fruit and vegetable products, household access to fortified foods, child and mother iron and vitamin A supplementation coverage, household ownership and child utilization of insecticide treated bednets, caregiver reported practices during child illness and child deworming coverage.

time points for an association between measures of animal food production or consumption and the risk of anaemia in children 24-59 mo. In general, household production and consumption of animal source foods did not differ significantly between 2000 and 2004, despite the fact that this was a specific objective of the MICAH program efforts in all three countries. In addition, based on the indicators used to assess child intake of animal source foods, evidence for an increase over time was available for only one country. In Ghana, the proportion of children who reported consuming meat or liver at least once in the seven days preceding the survey increased from 56.8% to 66.9% between 2000 and 2004. When this characteristic was compared with anaemia status, there was some evidence ($p<0.15$) for decreased severity of anaemia among children who had consumed some meat in the past week. However, in Malawi and Tanzania, there was no evidence for a protective effect of some meat intake. Due to the imprecise nature of these measures of access to and intake of animal source foods among children, it is not surprising to see the lack of any significant relationship between them and the risk of anaemia. Few studies have documented the effectiveness of animal production and dietary diversification/modification interventions on child anaemia outcomes (Leroy & Frongillo, 2007). However, in a community-based dietary diversification/ modification trial in Malawi, an increase in the consumption of animal source foods, mainly fish, was accompanied by improved intake of vitamin B12 and a lower prevalence of anaemia in children benefiting from the intervention compared to controls, even though iron intake remained inadequate in both groups (Yeudall *et al.*, 2002; Yeudall *et al.*, 2005). There is a need for developing and using more precise methods of assessing dietary intake in future studies on anaemia.

Indicators related to child care practices were also examined for their association with anaemia. Children whose parents reported they received iron and vitamin A supplements and were fully immunized were expected to be at lower risk of anaemia compared to children not benefiting from these practices. Surprisingly, there was little evidence for a protective effect of iron supplementation in those datasets where this information was collected. In Ghana, where iron supplementation coverage was over 80% at both time points, there was no association between iron supplementation and anaemia status in 2000 and only a tendency ($p<0.15$) for a protective effect in 2004

among those children whose mothers reported accessing iron supplements for their children U5. The lack of specificity of this indicator in Ghana may have contributed to the weak association. The same held true for children in Malawi in 2004, where no association was found between iron supplementation and the risk of anaemia. In Tanzania, where the question was asked for each specific child, there was little evidence for a protective effect of iron supplementation.

Iron deficiency is estimated to affect over half of the children in these countries (Stoltzfus *et al.*, 2004b) and therefore a protective effect of iron supplementation was expected. While the efficacy of iron supplementation to reduce anaemia has been demonstrated in controlled settings, the impact of both daily and weekly iron supplementation is considerably lower in unsupervised contexts, often due to low compliance (Beaton & McCabe, 1999). In our study, compliance was assessed for children U5 only in the 2004 survey by Malawi and Tanzania. In Malawi, roughly two thirds of households with children 6-59 mo reported receiving weekly iron supplements for children and virtually all (98.5%) of these were reported to also consume them (World Vision Canada, 2006b). In our study sample from Tanzania in 2004, one third of the children were reported to receive iron supplements regularly and all (100%) of them were reported to take all the iron provided[25]. While compliance was not directly assessed during the survey in Ghana, program monitoring of this indicator for children U5 suggested high levels of compliance (92-95%) from 2002 to 2004. Although lower than desired compliance cannot be ruled out, it is likely not the sole reason for the observed absence of association in children who reported receiving iron supplements. Given the high levels of iron-absorption inhibitors in the traditional diets as well as underlying chronic inflammation due to frequent illness and malaria-related morbidity, it is very possible that the supplemental iron was not absorbed effectively by the majority of children.

A healthy environment, defined here in terms of household access to potable water source and use of sanitary toilet facilities, was also tested for its association with the risk of anaemia. Children from households with access to potable water and reported

[25] Compliance was 93% in the combined sample of study and excluded children.

using private and improved toilet facilities were expected to be at lower risk of anaemia in bivariate analyses, although this effect was expected to be negligible in multivariate models when indicators of morbidity were included.

Results showed very little evidence of increased risk for anaemia or lower mean haemoglobin level associated with use of a non-potable water source in the dry season. Results were similar when the rainy season water source was used (data not shown). There was some evidence in Ghana in 2000 for an increased risk of anaemia among children from households who reported using a potable water source, an unexpected direction of association that showed a similar tendency in the multivariate model. One possible interpretation of this finding is that the program worked to improve access to potable water sources in the most remote communities, where isolation, poverty and low education levels are associated with a higher risk of anaemia among children. Thus, while these communities may have benefited from a potable water source, such as a borehole, during the project period, this one change may not have been sufficient to achieve a reduction in the risk for anaemia among children at this point. It is notable that this tendency for increased risk was not observed at the bivariate level in 2004. In Malawi and Tanzania, there was no evidence for increased risk of mild or moderate/severe anaemia among children from households who reported using a non-potable water source. Better household water supply has been associated with a decreased risk of anaemia in other contexts (Villamor *et al.*, 2000).

The results of the analysis of the relationship between anaemia and type of toilet facility used by the household showed an increased risk of anaemia among children from households who reported using the bush or field as their toilet facilities compared to those reporting the use of private or improved toilet facilities. In Ghana, this practice increased the risk of mild anaemia by two times and in Tanzania, it increased the risk of moderate/severe anaemia by over 1.5 times. In these contexts, families who do not have access to their own toilet facility are generally of lower socioeconomic status. Use of the bush or field as a toilet is associated with increased vulnerability to soil-transmitted helminth infections and this may account for the increased risk of anaemia associated

with this factor, independent of both child morbidity (illness in the past two days) and household relative wealth status.

#### 7.4.2.4 Basic causes

The risk of mild and moderate/severe anaemia associated with basic causes, including household wealth rank, maternal education and proximity to a health facility, was tested for evidence of an attenuation over time, based on the belief that these factors would become less important in the context of a program that is intervening at the level of immediate and underlying causes of anaemia.

A household's relative wealth rank was expected to be associated with anaemia initially, as children from poorer households were expected to have less nutritious diets, be exposed to more illness and vulnerable to its negative effects, and benefit less from adequate health care (Victora *et al.*, 2003). Similar to other studies looking at the risk factors for child anaemia, our study found some evidence in univariate analyses for an increased risk of anaemia among children from poorer households but this did not remain significant when other more direct risk factors were included in multivariate models (Kahigwa *et al.*, 2002; Osorio *et al.*, 2004; Siegel *et al.*, 2005; Ong'echa *et al.*, 2006; Ronald *et al.*, 2006; Ngnie-Teta *et al.*, 2007). Only a few studies have shown an independent association of household SES and child anaemia in models that adjust for child age, sex, height-for-age and morbidity (Adish *et al.*, 1999; Desai *et al.*, 2005; Ngnie-Teta *et al.*, 2007) and each of these used a different measure of SES as well as a different anaemia-related outcome. In our study, household wealth ranking was strongly associated with child stunting (data not shown) and therefore trusted as a reasonable measure of relative economic status.

The challenge for program interventions to equally benefit children across all socioeconomic groups has been highlighted elsewhere (Victora *et al.*, 2003). Although the MICAH program was targeted to households in rural communities that were identified as being under-serviced and at greater risk of undernutrition, possible areas of unequal benefit include the capacity to participate in program activities and have the resources required to adopt new practices. For example, program staff in Ghana reported

that poorer households were less likely to participate in latrine construction efforts, due to the requirement that households contribute labour to the construction process. In both Ghana and Malawi, community members interested in receiving small animal inputs from the program were required to first build appropriate animal housing, based on training given by agricultural extension agents.

An analysis of the equity of distribution of benefits and outcomes for the MICAH program in Ethiopia and Malawi after the first phase concluded that the program was very effective in targeting micronutrient and health activities but that there was some evidence for a distribution of benefits that favoured the asset-rich households (Cummings *et al.*, 2004). In that study in Malawi, better off households were more likely to have iodized salt, to know the causes of anaemia, and to have appropriate latrines. Better off households were less likely to have anaemia. There was no significant relationship between iron tablet distribution and asset level, however, suggesting a successful program delivery technique that was not biased against the poor.

A recent analysis of the "coverage gap" for essential maternal and child health interventions in 54 countries found that in-country patterns of inequality (i.e. lower coverage in poor households and higher coverage in more wealthy households) were persistent over time and changed only gradually if at all (Boerma *et al.*, 2008). The estimates by this group for the period between 1996 and 2004 showed that the difference in coverage between the poorest and wealthiest was lowest in Malawi (19% in 2000 and 18% in 2004), intermediate in Tanzania (23% in 1996 and 25% in 2004) and highest in Ghana (26% in 1998 and 31% in 2003).

Maternal education level has been shown to play an important role in child nutrition and caring practices, with higher maternal education linked to improved quality of a child's diet (longer or more exclusive breastfeeding, greater intake of protein and micronutrients), better physical growth and higher haemoglobin level (Wachs *et al.*, 2005). In our analysis, the measure of maternal education was limited to a two-level variable distinguishing between women who reported having some formal education (e.g. primary or secondary school) and those who had informal (e.g. Koran, literacy) or no education. We expected that children whose mothers had no formal education would

be at increased risk of anaemia initially and that this risk relationship would decrease between 2000 and 2004, due to the mitigating effect of program education efforts directly targeted to mothers. However, our results showed no clear evidence at the univariate level for an association between maternal formal education and children's risk of anaemia or lower mean haemoglobin. Inclusion of this variable in the multivariate models resulted in similar findings, although there was some evidence for a tendency toward increased risk of moderate/severe anaemia among children in Malawi whose mothers had no formal education. These findings may show that other risk factors for anaemia are more important than a mother's education level or that other caregivers play a more important role in child care and feeding practices known to influence anaemia in young children. Higher community education levels have been shown to mitigate the risk of negative child health outcomes associated with poor maternal education (Gessner *et al.*, 2010). However, these results may also be due to the insensitivity of the measure of maternal education used in the analysis. In preliminary data analysis, differentiating between mothers with primary versus secondary or higher levels of education in Malawi revealed a linear trend in the association between maternal education level and child anaemia risk. Children whose mothers had no formal education had the highest levels of anaemia and those whose mothers had at least some secondary level education had the lowest levels of anaemia (data not shown). Due to the sample size limitations of this study and the low number of women with a secondary level of education in these contexts, it was not possible to use a three-level variable for all countries and this may have limited our ability to observe the true nature of the risk relationship between maternal education and child anaemia.

Proximity to a health facility was included in the analysis as a measure of the remoteness of the child's household and a proxy for level of access to health services. Children living at a greater distance from a health facility were expected to be at increased risk of anaemia, especially since other indicators of access to health services for children were not available for inclusion in the models. We hypothesized that this risk relationship would be attenuated over time, given the emphasis of the program interventions on improving access to health and nutrition services at the community level, including program-related services as well as support for MOH routine outreach

services. Results at the bivariate and multivariate levels were consistent – only in Ghana was there a strong risk relationship between proximity to a health facility and anaemia status. In this context, children living in a community without a health facility were at increased risk of moderate/severe anaemia and this risk increased with greater distance from the nearest health facility. For children over 5 km from a health facility, there was also a tendency for increased risk of mild anaemia. While there was evidence at the bivariate level that the risk relationship was strong in 2000 but absent in 2004, this variation by year was not tested at the multivariate level. Nonetheless, there is some evidence in this country context that children living further away from health facilities are more vulnerable and that delivery of health and nutrition interventions at the community level may help to buffer this, especially for remote communities that are directly targeted by such programs.

The absence of similar evidence in Malawi and Tanzania raises the question of why this variable was not a significant risk factor for anaemia in these countries. In fact, in Malawi, children in the intermediate distance category (living within 5 km) had a *lower* risk of moderate/severe anaemia (RR 0.76; 95% CI 0.59, 0.98) compared to those living closer to a health facility. One other cross-sectional study in Kenya found that proximity to a health facility was not associated with the prevalence of anaemia in young children (Akhwale *et al.*, 2004).

The validity of this variable as a proxy for remoteness and access to health services may be questioned. Distance in itself may not be the most important factor determining a child's access to essential health services; both consumer and health facility attributes interact to produce different responses from different individuals (Joseph & Poyner, 1982). An in-depth study of factors associated with health facility utilization in Ghana found that distance was strongly negatively correlated with utilization, but income was also strongly associated and service cost, education, waiting time and transport cost also were independently associated with utilization (Buor, 2003). A recent study in Kenya found that for every 1 km increase in distance of residence from a clinic, the rate of clinic visits decreased by 34% (95% CI, 31–37%) from the previous kilometre (Feikin *et al.*, 2009). A similar negative association between distance

to health facility and vaccination coverage was observed in Haiti, where a 47% and 66% decrease in the odds of vaccination were observed at 46-60 and more than 60 minutes walk time to the nearest health care service facility, respectively (Muula *et al.*, 2009). Increasing distance to health clinics has also been shown to be associated with lower hospital admission rates for severe malaria cases (Schellenberg *et al.*, 1998).

#### 7.4.2.5 Other child characteristics

In our study, we found that children from the oldest age group (48-59 mo) were consistently at a lower risk of moderate/severe but not mild anaemia compared to children from the youngest age group (24-35 mo). Risk of any type of anaemia among children 36-47 mo was similar to children 24-35 mo. Longitudinal studies in African contexts have consistently shown an age-related evolution of anaemia, with children 6-30 mo at highest risk and a gradual decrease in risk thereafter (Cornet *et al.*, 1998; McElroy *et al.*, 1999). Cross-sectional studies also have highlighted the decrease in risk of anaemia among children over two years of age (Schellenberg *et al.*, 2003; Eliades *et al.*, 2006; Ronald *et al.*, 2006; Ngnie-Teta *et al.*, 2007; Custodio *et al.*, 2008) and the tendency for higher prevalence of severe anaemia in children under two years of age (Stoltzfus *et al.*, 2000). These findings reinforce the importance of assessing anaemia by age groups in population studies and not simply looking at anaemia rates in all children U5.

Although this age-associated trend is commonly observed in these contexts and was an expected finding in 2000, we expected the risk of anaemia and mean haemoglobin levels among the younger children to be more similar to older children in 2004. Since program interventions commenced in most areas in 1998-99, children 24-59 mo assessed in 2004 were expected to have been exposed to the integrated health and nutrition program interventions throughout their early years, the period of greatest vulnerability and the period during which the largest response to intervention was expected (Ruel *et al.*, 2008). Enhanced maternal nutrition as a result of program interventions that targeted all women of childbearing age in these areas and focused on improved nutrition and health during pregnancy was expected to improve the child's health and nutritional status at infancy, and provide a better starting point in the child's

development. Thus, we expected that between 2000 and 2004 there would be less disparity in the risk of anaemia between the youngest and oldest age groups.

One possible reason for the stable relationship between young age and anaemia risk is that the key period of vulnerability (0-23 mo) for the development of iron and other nutrient deficiencies was not adequately addressed by program interventions designed to improve infant and young child feeding practices. This is supported by the fact that little progress was made in reducing child stunting in these populations, another measure of the effectiveness of child nutrition interventions in the first two years of life. Evidence for the scope, intensity and effectiveness of MICAH interventions designed to improve child feeding practices is limited. Although program evaluation results showed increased exclusive breastfeeding rates in all three country contexts during this period of time, little change in the types of complementary foods given to children was found (World Vision Canada, 2006a; 2006b; 2006c). Therefore, it is unlikely that the changes observed during this period of time were of sufficient magnitude to effect a change in the age-anaemia risk relationship. Furthermore, recent evidence suggests that even highly effective complementary feeding interventions may not be sufficient to prevent all stunting, based on observations in Malawi that 40% of the cumulative deficit in stature occurred before six months of age (Dewey & Huffman, 2009). Improving the micronutrient status of women during pregnancy through interventions like MMN supplementation can also contribute to meaningful improvements in the growth and development of children by two years of age (Shrimpton *et al.*, 2009).

## 7.5 Public health importance of undernutrition and morbidity in anaemia control efforts

Anaemia control in populations is a public health priority globally. In developing country contexts, where resources for public health programmes are normally outstripped by the level of demand, prioritization of interventions in terms of their existence and scope is inevitable. We calculated population attributable risk (PAR) estimates in order to quantify the potential impact in the population of addressing specific preventable risk factors for anaemia, specifically stunting, malaria and recent

illness. The comparison of results across countries showed three distinct context-specific patterns. In one pattern, where stunting levels are moderate and malaria prevalence is relatively low (e.g. Ghana program areas), about one fifth of moderate/severe anaemia was attributable to stunting. A different pattern was observed in Malawi, where higher levels of malaria among young children initially accounted for one fifth of moderate/severe anaemia cases (as seen in 2000) and stunting accounted for a smaller proportion of these cases. In this context in 2004 with a lower prevalence of malaria but similar prevalence of stunting, the proportion of moderate/severe anaemia cases attributable to malaria was much lower (3.4%) and the proportion attributable to stunting was higher (15.3%). Finally, in Tanzania, the PAR for stunting was low at both time points, despite a marked decrease in the prevalence of this risk factor, while the PAR for both malaria and recent illness showed a tendency to be higher in 2004 compared to 2000. This occurred despite the fact that only the prevalence of malaria was higher in 2004 and the prevalence of recent illness was actually lower in 2004 than in 2000.

Similar calculations were made using data collected among children 7-13 y on Pemba Island, Zanzibar, where only 6% of anaemia and IDA was attributable to stunting (prevalence 48%) and only 6% of anaemia and 10% of IDA were attributable to malaria infection (prevalence 61%) (Stoltzfus *et al.*, 1997a). In these older school children, one fourth of anaemia and one third of IDA were attributable to hookworm infection (prevalence 94%), a risk factor not measured in our study but expected to be of much lower prevalence and intensity in younger children. This was the case in Kenya among children 6-76 mo where 29% were infected with hookworm and 34% had malaria parasitaemia (stunting prevalence not reported). In this sample, the PAR for anaemia was only 4% for hookworm and 7% for malaria infection (Brooker *et al.*, 1999).

These findings are useful in public health policy discussions surrounding the level of effort and resources invested in interventions designed to reduce anaemia in young children. These results suggest that in contexts where malaria is of low to moderate transmission, anaemia control efforts targeted to preschool children should place a strong emphasis on reducing child undernutrition (as proxied by stunting)

alongside ongoing efforts to reduce morbidity associated with malaria and other child illnesses. However, where malaria transmission is moderate to high, reducing child anaemia requires a strong emphasis on both malaria control and prevention of undernutrition.

In addition, our findings showed that despite a lower prevalence of stunting in Ghana in 2004 compared to 2000, the risk of anaemia attributable to stunting was higher. One possible interpretation is that in populations where a substantial number of children become stunted, there is little that can be done to reduce anaemia and interventions that have been shown to be effective in other contexts may not be so in these groups. Although some studies have shown a poorer response to interventions among stunted children (Pedro *et al.*, 2004; Payne *et al.*, 2007), others have found an enhanced response (Chhagan *et al.*, 2009). A recent meta-analysis of the effect on child haemoglobin of multiple micronutrient supplementation with iron found that lower HAZ (<-0.9) was a significant predictor of a positive effect of the intervention (Gera *et al.*, 2009); however, the cut-off used was not adequately reflective of the characteristics of children with moderate and severe stunting.

A related point to be made here, in light of the PAR results for stunting in Ghana, is that an observed decrease in the prevalence of a risk factor does not automatically imply that the proportion of risk of the outcome attributable to this factor has also decreased. A similar incongruent trend was observed in Tanzania for recent illness in 2004, although in a much smaller sample and therefore less accurate estimates.

## 7.6 Implications for programming

These results confirm the complexity of the problem of anaemia and reinforce international recommendations for an integrated, multifactorial and multisectorial approach to combat the problem (WHO/UNICEF, 2004). The risk factor analysis showed that the measures of undernutrition and morbidity used in this study can vary in their magnitude of association with anaemia status in different country contexts. This information is important for contextualizing the design of anaemia control programmes. In particular, the relative importance of malaria, other illness and stunting as risk factors

for child anaemia should be assessed and careful attention given to both the unique and synergistic pathways by which these influence child nutrition and health. Stunting is used in this regard as a proxy indicator for chronic nutritional insufficiency for which data is commonly available at the field level.

Do the results overall support the hypothesis that an integrated approach reduces child vulnerability and offers the potential for public health nutrition interventions to decrease the risk of anaemia associated with exposure to risk factors? Overall, there was minimal evidence for this buffering effect of the MICAH program. While it is likely that the interventions addressed child vulnerability to a certain extent, this effect was not sufficient to enable stunted or malaria-positive children to adequately respond to interventions in these contexts. In general, children who were stunted or had some type of morbidity were still at higher risk of anaemia, both mild and moderate/severe, with little change in vulnerability observed over time. While this does not mean that a buffering effect is impossible to achieve, these findings suggest that different or more intensive strategies may be needed to overcome the barriers experienced by these vulnerable children. A reduction in vulnerability encompasses two aspects – reduction in exposure and enhancement of capacity to respond. It may be that the program was more successful in reducing exposure than in enhancing capacity to respond.

Further consideration of differential responsiveness to health and nutrition interventions is merited (Solomons, 2002), in parallel with the broader discussion of differential vulnerability in the literature on equity and social determinants of health (WHO, 2007a; Barros *et al.*, 2010). The inter-country differences observed in our study of children living in areas benefiting from largely similar packages of health and nutrition interventions reinforce the finding by various controlled studies that differences likely exist in responsiveness to some interventions at the individual (e.g. genetic factors), sub-group (e.g. stunted, HIV-positive) and/or population (e.g. rural poor) levels. This may be an important but often unmeasured explanation for the different trends in outcome observed over time. Differential responsiveness is a critical factor to be considered at all stages of public health and nutrition programming, including program design and effectiveness evaluations. For program design purposes,

specifically, increased attention to contextualizing interventions is required to ensure that the unique needs of groups likely to have low responsiveness are addressed. Program evaluations must also look at subgroup responsiveness when assessing the effectiveness of interventions, a step often reserved for controlled studies. Further exploration of the degree to which varying responsiveness may jeopardize the success of anaemia control efforts in real-life settings is needed, particularly in sub-Saharan Africa where the aetiology of anaemia is so complex,

Consideration of the minimum period of time required to observe measurable changes in child vulnerability is also merited. Our study made the assumption that the cumulative effect of health and nutrition interventions delivered in targeted areas would be measurable among children 24-59 mo of age in a four-year period of time. While this may be reasonable for some risk factors, such as malaria, it may be insufficient for others, such as pervasive iron deficiency and child undernutrition. Given the complexity of the social conditions in which these nutrient deficiencies and health outcomes develop and persist, efforts to reduce vulnerability may require investment for multiple generations before measurable change is observed. Nonetheless, further testing of the utility of the child vulnerability concept in the field of public health nutrition, and particularly in the analysis of anaemia program effectiveness, is recommended.

The present finding that about one fifth of moderate/severe anaemia cases were attributable to stunting in two of the three countries highlights the importance of addressing the causes of this chronic undernutrition that results in both linear growth retardation and anaemia. This is in keeping with recent high-level advocacy efforts calling for the sharp scale-up of evidence-based cost-effective interventions to prevent and treat undernutrition, with highest priority to the minus 9 to 24 month window of opportunity in early childhood (2010). Although improvements in program design can be made, the experience of the program reviewed in this study and that of other well-funded, well-designed programs is that effective delivery of nutrition interventions to target groups that results in meaningful improvements in child nutrition outcomes is actually quite difficult in real-life settings. This was highlighted in a recent evaluation of a large-scale child survival program. The Accelerated Child Survival and Development

initiative of UNICEF was designed to improve child survival but a recent evaluation of these efforts found that no changes in nutritional status of children were observed in districts where these efforts were invested and interventions effective in combating undernutrition, which underlies at least a third of child deaths, were reported by country teams as receiving low priority in their program plans (Bryce *et al.*, 2010). To address the implementation gap, the international development community will need to move beyond controlled studies and invest strategically in enhancing capacity to locally develop interventions and for effectiveness and operational research (Heikens *et al.*, 2008).

Due to the critical concern with adequate iron status during the early years of child development, international anaemia control policy and advocacy efforts have prioritized the control of iron deficiency as a primary cause of anaemia. However, our results suggest that a broader focus is needed to successfully address child anaemia in contexts like Ghana, Malawi and Tanzania where iron deficiency is only one of several key nutrient deficiencies to which young children are chronically exposed. As expressed by Muller and colleagues:

> "… instead of developing ever more complex supplementation schemes for malnourished populations, it appears to be more appropriate to address the PEM problem more broadly. ...Fast and effective reduction of undernutrition requires both economic growth in low income countries and direct action. The latter includes sustainable community-based multisectorial programmes on dietary modification and diversification; attention to water management, especially in irrigated agriculture; and improving public health. The links between macro and micro conditions for nutritional improvement are still poorly understood. Research into these might have a high pay-off, exceeding that focused on perfecting specific nutrient interventions." (2002, p.2)

A more intensive focus on young child feeding practices may be needed to complement the broader efforts at disease control and micronutrient supplementation. Behaviour change and communication interventions that are designed based on effective, feasible and locally acceptable child care and feeding practices and delivered

in a targeted manner to mothers at the appropriate times when this information is most needed, have been shown to be effective in reducing child undernutrition (Penny *et al.*, 2005; Ruel *et al.*, 2008). While large-scale efforts to improve policy and program guidance in this regard are much needed, formative research and cultural sensitivity must also guide each program's efforts to contextualize these international guidelines for local community application. Enhanced monitoring and evaluation of specific program objectives, such as young child feeding practices, is also recommended. Since the MICAH program was designed, further progress has been made in developing standards and defining indicators for appropriate infant and young child feeding practices (PAHO/WHO, 2003; WHO, 2005a; WHO/UNICEF/IFPRI/UC Davis/USAID/FANTA, 2008) and this is expected to contribute to improved program design, implementation and evaluation.

Our results also reinforce the importance of ensuring that interventions directly address vulnerabilities experienced by the poorest children. "Pro-poor" interventions have larger aggregate benefits, especially in sub-Saharan Africa where inequities between the most poor and the least poor are high, because they deliver environmental and nutritional interventions to children who are most vulnerable to both the morbidity and mortality associated with these exposures (Gakidou *et al.*, 2007). Anaemia control program interventions must seek to narrow the gap in coverage between the most and least poor households and specifically focus on building the capacity of poorer households to participate in and benefit from the interventions. Since evidence indicates that poor households face the greatest burdens of both HIV and non-communicable diseases, and that these are associated with worse child health outcomes, effectively addressing the burden of adult non-communicable diseases and HIV is also required in order to achieve progress in this regard (Stuckler *et al.*, 2010).

Finally, while anaemia control programs rightly prioritize children under two years of age where resources are limited, children over two years continue to carry a heavy burden of anaemia in these contexts and should also benefit from interventions where resources allow. Different strategies may be needed to address anaemia in these older children, given that they are usually eating from the family pot, at greater risk of soil-transmitted helminth infections, at decreased risk of acute malaria episodes due to acquired immunity and less likely to be in attendance for routine health services. There is a particular danger that these children may fall through the gap between interventions designed to address iron deficiency in children under two years of age and those designed for adults. For example, children 24-59 mo will likely not benefit from the higher levels of iron fortificant in complementary foods promoted for use by younger children and may also have inadequate intake of iron from other foods fortified at levels designed for the general population.

"In its obsession with the application of technological solutions to complex social and economic problems, the international community has developed targeted approaches to control acute respiratory infections and diarrhoea, and is now promoting vaccines against the specific aetiological agents responsible for ARI and diarrhoea. The fact that most deaths due to these causes are really the result of malnutrition and poverty seems to be conveniently forgotten."

(Mulholland, 2005)

# CHAPTER 8: CONCLUSION

# 8 Conclusion

In May 2002, the United Nations General Assembly at its special session on children endorsed several goals to be achieved by 2010, including the reduction of child mortality and malnutrition. One of the specific strategies included was "...reduce by one third the prevalence of anaemia, including iron deficiency, by 2010; and accelerate progress towards reduction of other micronutrient deficiencies, through dietary diversification, food fortification and supplementation" (UN General Assembly Res S27-2E, 11 October 2002). Although the past two decades have seen a dramatic increase in the attention given to the problem of anaemia globally, both in terms of research and programs, it appears certain that this goal will not be achieved this year. With so few examples of programs that have successfully delivered a package of integrated nutrition and health interventions at scale, we must look instead to smaller programs that provide evidence for what may be achieved in the next decade.

The MICAH program is an example of a well-designed community-based program that used multiple, integrated interventions to address child anaemia in several African countries. The evaluation data collected during the course of the program in Ghana, Malawi and Tanzania and analyzed in this study have provided valuable insights to the risk factors for mild and moderate/severe anaemia in young children and what changes may occur in these risk relationships over the course of the intervention. What is most surprising is that in spite of an evidence-based program design and moderate intensity of implementation, younger children remained at higher risk of anaemia, reductions in anaemia appeared to be primarily attributable to reductions in the prevalence of exposure to risk factors, and children who were better off (e.g. non-stunted, no malaria) showed higher rates of improvement over time in moderate/severe anaemia. Given that the data were insufficient to fully explain the variation in anaemia reduction across countries, further investigation into what indicators may better explain the pathways of impact of future child anaemia control programs is warranted.

In unison with other voices calling for a revolution in the international development community and its approach to improving child survival and development,

the results of this work support the idea that single, vertical interventions are not an adequate response to the problem of anaemia in young children and that comprehensive packages of interventions that are designed based on the context-specific causes of anaemia are needed. These results suggest that high levels of child undernutrition are a barrier to further progress in reducing anaemia in developing countries. Although some recent landmark publications have attempted to mark the pathway toward reducing maternal and child undernutrition, it remains to be seen whether nations can respond with effective programs to achieve these goals.

# References

(2010) Scaling Up Nutrition: a framework for action. *Food Nutr Bull* **31**, 178-186.

Abdulla S, Schellenberg JA, Nathan R, Mukasa O, Marchant T, Smith T, Tanner M & Lengeler C (2001) Impact on malaria morbidity of a programme supplying insecticide treated nets in children aged under 2 years in Tanzania: community cross sectional study. *BMJ* **322**, 270-273.

Abrams SA, Mushi A, Hilmers DC, Griffin IJ, Davila P & Allen L (2003) A multinutrient-fortified beverage enhances the nutritional status of children in Botswana. *J Nutr* **133**, 1834-1840.

Aburto NJ, Ramirez-Zea M, Neufeld LM & Flores-Ayala R (2009) Some indicators of nutritional status are associated with activity and exploration in infants at risk for vitamin and mineral deficiencies. *J Nutr* **139**, 1751-1757.

Adish AA, Esrey SA, Gyorkos TW & Johns T (1999) Risk factors for iron deficiency anaemia in preschool children in northern Ethiopia. *Public Health Nutr* **2**, 243-252.

Adu-Afarwuah S, Lartey A, Brown KH, Zlotkin S, Briend A & Dewey KG (2008) Home fortification of complementary foods with micronutrient supplements is well accepted and has positive effects on infant iron status in Ghana. *Am J Clin Nutr* **87**, 929-938.

Agho KE, Dibley MJ, D'Este C & Gibberd R (2008) Factors associated with haemoglobin concentration among Timor-Leste children aged 6-59 months. *J Health Popul Nutr* **26**, 200-209.

Agresti A (2007) *An introduction to categorical data analysis, 2nd edition*. Hoboken, NJ: JohnWiley & Sons, Inc.

Agte V, Jahagirdar M & Chiplonkar S (2006) GLV supplements increased plasma beta-carotene, vitamin C, zinc and hemoglobin in young healthy adults. *Eur J Nutr* **45**, 29-36.

Akhwale WS, Lum JK, Kaneko A, Eto H, Obonyo C, Bjorkman A & Kobayakawa T (2004) Anemia and malaria at different altitudes in the western highlands of Kenya. *Acta Trop* **91**, 167-175.

Akinkugbe FM (1980) Anaemia in a rural population in Nigeria (Ilora). *Ann Trop Med Parasitol* **74**, 625-633.

Alarcon K, Kolsteren PW, Prada AM, Chian AM, Velarde RE, Pecho IL & Hoeree TF (2004) Effects of separate delivery of zinc or zinc and vitamin A on hemoglobin response, growth, and diarrhea in young Peruvian children receiving iron therapy for anemia. *Am J Clin Nutr* **80**, 1276-1282.

Alderman H, Konde-Lule J, Sebuliba I, Bundy D & Hall A (2006) Effect on weight gain of routinely giving albendazole to preschool children during child health days in Uganda: cluster randomised controlled trial. *BMJ* **333**, 122.

Allen L & Ahluwalia N (1997) Improving iron status through diet: the application of knowledge concerning dietary iron bioavailability in human populations.

Allen L, De Benoist B, Dary O & Hurrell R (2006) *Guidelines on food fortification with micronutrients*. Geneva: WHO/FAO.

Allen LH (2002) Iron supplements: scientific issues concerning efficacy and implications for research and programs. *J Nutr* **132**, 813S-819S.

Allen LH (2008) To what extent can food-based approaches improve micronutrient status? *Asia Pac J Clin Nutr* **17 Suppl 1**, 103-105.

Allen LH, Peerson JM & Olney DK (2009) Provision of Multiple Rather Than Two or Fewer Micronutrients More Effectively Improves Growth and Other Outcomes in Micronutrient-Deficient Children and Adults. *J Nutr*.

Allen LH, Rosado JL, Casterline JE, Lopez P, Munoz E, Garcia OP & Martinez H (2000) Lack of hemoglobin response to iron supplementation in anemic mexican preschoolers with multiple micronutrient deficiencies. *Am J Clin Nutr* **71**, 1485-1494.

Allen SJ, O'Donnell A, Alexander ND, Alpers MP, Peto TE, Clegg JB & Weatherall DJ (1997) alpha+-Thalassemia protects children against disease caused by other infections as well as malaria. *Proc Natl Acad Sci U S A* **94**, 14736-14741.

Allen SJ, Rowe P, Allsopp CE, Riley EM, Jakobsen PH, Hill AV & Greenwood BM (1993) A prospective study of the influence of alpha thalassaemia on morbidity from malaria and immune responses to defined Plasmodium falciparum antigens in Gambian children. *Trans R Soc Trop Med Hyg* **87**, 282-285.

Alonzo Gonzalez M, Menendez C, Font F, Kahigwa E, Kimario J, Mshinda H, Tanner M, Bosch-Capblanch X & Alonso PL (2000) Cost-effectiveness of iron supplementation and malaria chemoprophylaxis in the prevention of anaemia and malaria among Tanzanian infants. *Bull World Health Organ* **78**, 97-107.

Amoaful EF (2001) Planning a national food-based strategy for sustainable control of vitamin A deficiency in Ghana: steps toward transition from supplementation. *Food Nutr Bull* **22**, 5.

Andang'o PE, Osendarp SJ, Ayah R, West CE, Mwaniki DL, De Wolf CA, Kraaijenhagen R, Kok FJ & Verhoef H (2007) Efficacy of iron-fortified whole maize flour on iron status of schoolchildren in Kenya: a randomised controlled trial. *Lancet* **369**, 1799-1806.

Arcanjo FP, Pinto VP, Coelho MR, Amancio OM & Magalhaes SM (2008) Anemia reduction in preschool children with the addition of low doses of iron to school meals. *J Trop Pediatr* **54**, 243-247.

Arifeen SE, Hoque DM, Akter T, Rahman M, Hoque ME, Begum K, Chowdhury EK, Khan R, Blum LS, Ahmed S, Hossain MA, Siddik A, Begum N, Sadeq-ur Rahman Q, Haque TM, Billah SM, Islam M, Rumi RA, Law E, Al-Helal ZA, Baqui AH, Schellenberg J, Adam T, Moulton LH, Habicht JP, Scherpbier RW, Victora CG, Bryce J & Black RE (2009) Effect of the Integrated Management of Childhood Illness strategy on childhood mortality and nutrition in a rural area in Bangladesh: a cluster randomised trial. *Lancet* **374**, 393-403.

Armstrong R, Waters E, Moore L, Riggs E, Cuervo LG, Lumbiganon P & Hawe P (2008) Improving the reporting of public health intervention research: advancing TREND and CONSORT. *J Public Health (Oxf)* **30**, 103-109.

Armstrong Schellenberg JR, Adam T, Mshinda H, Masanja H, Kabadi G, Mukasa O, John T, Charles S, Nathan R, Wilczynska K, Mgalula L, Mbuya C, Mswia R, Manzi F, de Savigny D, Schellenberg D & Victora C (2004) Effectiveness and

cost of facility-based Integrated Management of Childhood Illness (IMCI) in Tanzania. *Lancet* **364**, 1583-1594.

Asaolu SO & Ofoezie IE (2003) The role of health education and sanitation in the control of helminth infections. *Acta Trop* **86**, 283-294.

Asobayire FS, Adou P, Davidsson L, Cook JD & Hurrell RF (2001) Prevalence of iron deficiency with and without concurrent anemia in population groups with high prevalences of malaria and other infections: a study in Cote d'Ivoire. *Am J Clin Nutr* **74**, 776-782.

Barros FC, Victora CG, Scherpbier R & Gwatkin D (2010) Socioeconomic inequities in the health and nutrition of children in low/middle income countries. *Rev Saude Publica* **44**, 1-16.

Bates I, Fenton C, Gruber J, Lalloo D, Lara AM, Squire SB, Theobald S, Thomson R & Tolhurst R (2004a) Vulnerability to malaria, tuberculosis, and HIV/AIDS infection and disease. Part II: Determinants operating at environmental and institutional level. *Lancet Infect Dis* **4**, 368-375.

Bates I, Fenton C, Gruber J, Lalloo D, Medina Lara A, Squire SB, Theobald S, Thomson R & Tolhurst R (2004b) Vulnerability to malaria, tuberculosis, and HIV/AIDS infection and disease. Part 1: determinants operating at individual and household level. *Lancet Infect Dis* **4**, 267-277.

Beaton G, Martorell R, Aronson KJ, Edmonston B, McCabe G, Ross AC & Harvey B (1993) Effectiveness of vitamin A supplementation in the control of young child morbidity and mortality in developing countries - Nutrition policy discussion paper No. 13. Geneva: United Nations, Administrative Committee on Coordination and Subcommittee on Nutrition.

Beaton G & McCabe G (1999) Efficacy of intermittent iron supplementation in the control of iron deficiency anaemia in developing countries: an analysis of experience. Ottawa, Canada: The Micronutrient Initiative.

Beaton GH, Corey PN & Steele C (1989) Conceptual and methodological issues regarding the epidemiology of iron deficiency and their implications for studies of the functional consequences of iron deficiency. *Am J Clin Nutr* **50**, 575-585; discussion 586-578.

Begin F, Santizo MC, Peerson JM, Torun B & Brown KH (2008) Effects of bovine serum concentrate, with or without supplemental micronutrients, on the growth, morbidity, and micronutrient status of young children in a low-income, peri-urban Guatemalan community. *Eur J Clin Nutr* **62**, 39-50.

Beinner MA, Velasquez-Melendez G, Pessoa MC & Greiner T (2010) Iron-fortified rice is as efficacious as supplemental iron drops in infants and young children. *J Nutr* **140**, 49-53.

Ben Rayana MC, Kolsteren P, Lefèvre P, Gharbi T, Khosrof-Ben Jaafar S & Beghin I (2002) Approche causale de l'anémie par carence en fer. *Options Méditerranéennes* **Sér. B**, 41-49.

Bennett S, Radalowicz A, Vella V & Tomkins A (1994) A computer simulation of household sampling schemes for health surveys in developing countries. *Int J Epidemiol* **23**, 1282-1291.

Berger J, Ninh NX, Khan NC, Nhien NV, Lien DK, Trung NQ & Khoi HH (2006) Efficacy of combined iron and zinc supplementation on micronutrient status and growth in Vietnamese infants. *Eur J Clin Nutr* **60**, 443-454.

Berger SG, de Pee S, Bloem MW, Halati S & Semba RD (2007) Malnutrition and morbidity are higher in children who are missed by periodic vitamin A capsule distribution for child survival in rural Indonesia. *J Nutr* **137**, 1328-1333.

Bernard J, Mtove G, Mandike R, Mtei F, Maxwell C & Reyburn H (2009) Equity and coverage of insecticide-treated bed nets in an area of intense transmission of Plasmodium falciparum in Tanzania. *Malar J* **8**, 65.

Berti PR, Krasevec J & FitzGerald S (2004) A review of the effectiveness of agriculture interventions in improving nutrition outcomes. *Public Health Nutr* **7**, 599-609.

Berti PR, Mildon A, Siekmans K, Main B & Macdonald C (2010) An adequacy evaluation of a 10-year, four-country nutrition and health programme. *Int J Epidemiol* **39**, 613-629.

Bethony J, Brooker S, Albonico M, Geiger SM, Loukas A, Diemert D & Hotez PJ (2006) Soil-transmitted helminth infections: ascariasis, trichuriasis, and hookworm. *Lancet* **367**, 1521-1532.

Bhandari N, Bahl R & Taneja S (2001) Effect of micronutrient supplementation on linear growth of children. *Br J Nutr* **85 Suppl 2**, S131-137.

Bhutta Z, Klemm R, Shahid F, Rizvi A, Rah JH & Christian P (2009) Treatment response to iron and folic acid alone is the same as with multivitamins and/or anthelminthics in severely anemic 6- to 24-month-old children. *J Nutr* **139**, 1568-1574.

Bhutta ZA, Ahmed T, Black RE, Cousens S, Dewey K, Giugliani E, Haider BA, Kirkwood B, Morris SS, Sachdev HP & Shekar M (2008a) What works? Interventions for maternal and child undernutrition and survival. *Lancet* **371**, 417-440.

Bhutta ZA, Ahmed T, Black RE, Cousens S, Dewey K, Giugliani E, Haider BA, Kirkwood B, Morris SS, Sachdev HPS, Shekar M & , for the Maternal and Child Undernutrition Study Group* (2008b) What works? Interventions for maternal and child undernutrition and survival. *Lancet* **371**, 417-440.

Binka FN, Ross DA, Morris SS, Kirkwood B, Arthur P, Dollimore N, Gyapong JO & Smith PG (1995) Vitamin A supplementation and childhood malaria in northern Ghana. *Am J Clin Nutr* **61**, 853-859.

Bisset S & Potvin L (2007) Expanding our conceptualization of program implementation: lessons from the genealogy of a school-based nutrition program. *Health Educ Res* **22**, 737-746.

Bloem MW, Wedel M, Egger RJ, Speek AJ, Schrijver J, Saowakontha S & Schreurs WH (1989) Iron metabolism and vitamin A deficiency in children in northeast Thailand. *Am J Clin Nutr* **50**, 332-338.

Bloem MW, Wedel M, van Agtmaal EJ, Speek AJ, Saowakontha S & Schreurs WH (1990) Vitamin A intervention: short-term effects of a single, oral, massive dose on iron metabolism. *Am J Clin Nutr* **51**, 76-79.

Bloland PB, Boriga DA, Ruebush TK, McCormick JB, Roberts JM, Oloo AJ, Hawley W, Lal A, Nahlen B & Campbell CC (1999) Longitudinal cohort study of the epidemiology of malaria infections in an area of intense malaria transmission II.

Descriptive epidemiology of malaria infection and disease among children. *Am J Trop Med Hyg* **60**, 641-648.

Boerma JT, Bryce J, Kinfu Y, Axelson H & Victora CG (2008) Mind the gap: equity and trends in coverage of maternal, newborn, and child health services in 54 Countdown countries. *Lancet* **371**, 1259-1267.

Booysen F, Van Der Berg S, Burger R, Von Maltitz M & Du Rand G (2008) Using an asset index to assess trends in poverty in seven sub-Saharan African countries. *World Development* **36**, 1113-1130.

Bosompem KM, Bentum IA, Otchere J, Anyan WK, Brown CA, Osada Y, Takeo S, Kojima S & Ohta N (2004) Infant schistosomiasis in Ghana: a survey in an irrigation community. *Trop Med Int Health* **9**, 917-922.

Brabin B, Prinsen-Geerligs P, Verhoeff F & Kazembe P (2003) Anaemia prevention for reduction of mortality in mothers and children. *Trans R Soc Trop Med Hyg* **97**, 36-38.

Brabin BJ, Premji Z & Verhoeff F (2001) An analysis of anemia and child mortality. *J Nutr* **131**, 636S-645S; discussion 646S-648S.

Branca F & Ferrari M (2002) Impact of micronutrient deficiencies on growth: the stunting syndrome. *Ann Nutr Metab* **46 Suppl 1**, 8-17.

Brewster DR & Greenwood BM (1993) Seasonal variation of paediatric diseases in The Gambia, west Africa. *Ann Trop Paediatr* **13**, 133-146.

Briand V, Watier L, JY LEH, Garcia A & Cot M (2005) Coinfection with Plasmodium falciparum and schistosoma haematobium: protective effect of schistosomiasis on malaria in senegalese children? *Am J Trop Med Hyg* **72**, 702-707.

Brooker S, Akhwale W, Pullan R, Estambale B, Clarke SE, Snow RW & Hotez PJ (2007) Epidemiology of plasmodium-helminth co-infection in Africa: populations at risk, potential impact on anemia, and prospects for combining control. *Am J Trop Med Hyg* **77**, 88-98.

Brooker S, Bethony J & Hotez PJ (2004) Human hookworm infection in the 21st century. *Adv Parasitol* **58**, 197-288.

Brooker S, Peshu N, Warn PA, Mosobo M, Guyatt HL, Marsh K & Snow RW (1999) The epidemiology of hookworm infection and its contribution to anaemia among pre-school children on the Kenyan coast. *Trans R Soc Trop Med Hyg* **93**, 240-246.

Brown KH, Black RE, Robertson AD & Becker S (1985) Effects of season and illness on the dietary intake of weanlings during longitudinal studies in rural Bangladesh. *Am J Clin Nutr* **41**, 343-355.

Brown KH, Peerson JM, Kimmons JE & Hotz C (2002) Options for achieving adequate intake from home-prepared complementary foods in low-income countries. In *Public health issues in infant and child nutrition.* [RE Black and KF Michaelsen, editors]. Philadelphia: Nestec Ltd, Vevey/Lippincott Williams & Wilkins.

Bryce J, Gilroy K, Jones G, Hazel E, Black RE & Victora CG (2010) The Accelerated Child Survival and Development programme in west Africa: a retrospective evaluation. *Lancet* **375**, 572-582.

Bunn HF (1986) *Hemoglobin: molecular, genetic and clinical aspects*. Philadelphia, PA: Saunders.

Buor D (2003) Analysing the primacy of distance in the utilization of health services in the Ahafo-Ano South district, Ghana. *Int J Health Plann Manage* **18**, 293-311.

Bushamuka VN, de Pee S, Talukder A, Kiess L, Panagides D, Taher A & Bloem MW (2005) Impact of a homestead gardening program on household food security and empowerment of women in Bangladesh. *Food Nutr Bull* **26**, 17-25.

Calis JC, van Hensbroek MB, de Haan RJ, Moons P, Brabin BJ & Bates I (2008) HIV-associated anemia in children: a systematic review from a global perspective. *AIDS* **22**, 1099-1112.

Carneiro IA, Drakeley CJ, Owusu-Agyei S, Mmbando B & Chandramohan D (2007) Haemoglobin and haematocrit: is the threefold conversion valid for assessing anaemia in malaria-endemic settings? *Malar J* **6**, 67.

Carneiro IA, Smith T, Lusingu JP, Malima R, Utzinger J & Drakeley CJ (2006) Modeling the relationship between the population prevalence of Plasmodium falciparum malaria and anemia. *Am J Trop Med Hyg* **75**, 82-89.

Castejon HV, Ortega P, Amaya D, Gomez G, Leal J & Castejon OJ (2004) Co-existence of anemia, vitamin A deficiency and growth retardation among children 24-84 months old in Maracaibo, Venezuela. *Nutr Neurosci* **7**, 113-119.

Caulfield LE, Richard SA & Black RE (2004) Undernutrition as an underlying cause of malaria morbidity and mortality in children less than five years old. *Am J Trop Med Hyg* **71**, 55-63.

Chanarin I (1999) Nutritional aspects of hematologic disorders. In *Modern nutrition in health and disease, 9th ed.* [ME Shils, JA Olson, M Shike and AC Ross, editors]. Baltimore: Williams & Wilkins.

Chaparro CM, Neufeld LM, Tena Alavez G, Eguia-Liz Cedillo R & Dewey KG (2006) Effect of timing of umbilical cord clamping on iron status in Mexican infants: a randomised controlled trial. *Lancet* **367**, 1997-2004.

Chatterjee A, Bosch RJ, Kupka R, Hunter DJ, Msamanga GI & Fawzi WW (2010) Predictors and consequences of anaemia among antiretroviral-naive HIV-infected and HIV-uninfected children in Tanzania. *Public Health Nutr* **13**, 289-296.

Checkley W, Gilman RH, Black RE, Epstein LD, Cabrera L, Sterling CR & Moulton LH (2004) Effect of water and sanitation on childhood health in a poor Peruvian peri-urban community. *Lancet* **363**, 112-118.

Chhagan MK, Van den Broeck J, Luabeya KK, Mpontshane N, Tomkins A & Bennish ML (2010) Effect on longitudinal growth and anemia of zinc or multiple micronutrients added to vitamin A: a randomized controlled trial in children aged 6-24 months. *BMC Public Health* **10**, 145.

Chhagan MK, Van den Broeck J, Luabeya KK, Mpontshane N, Tucker KL & Bennish ML (2009) Effect of micronutrient supplementation on diarrhoeal disease among stunted children in rural South Africa. *Eur J Clin Nutr* **63**, 850-857.

Cisse B, Sokhna C, Boulanger D, Milet J, Ba el H, Richardson K, Hallett R, Sutherland C, Simondon K, Simondon F, Alexander N, Gaye O, Targett G, Lines J, Greenwood B & Trape JF (2006) Seasonal intermittent preventive treatment with artesunate and sulfadoxine-pyrimethamine for prevention of malaria in Senegalese children: a randomised, placebo-controlled, double-blind trial. *Lancet* **367**, 659-667.

Clark TD, Mmiro F, Ndugwa C, Perry RT, Jackson JB, Melikian G & Semba RD (2002) Risk factors and cumulative incidence of anaemia among human immunodeficiency virus-infected children in Uganda. *Ann Trop Paediatr* **22**, 11-17.

Cole SR & Hernan MA (2002) Fallibility in estimating direct effects. *Int J Epidemiol* **31**, 163-165.

Colecraft E, Marquis GS, Aryeetey R, Sakyi-Dawson O, Lartey A, Ahunu B & Canacoo E (2006) Constraints on the use of animal source foods for young children in Ghana: a participatory rapid appraisal approach. *Ecology of Food and Nutrition* **45**, 351-377.

Cornet M, Le Hesran JY, Fievet N, Cot M, Personne P, Gounoue R, Beyeme M & Deloron P (1998) Prevalence of and risk factors for anemia in young children in southern Cameroon. *Am J Trop Med Hyg* **58**, 606-611.

Crawley J (2004) Reducing the burden of anemia in infants and young children in malaria-endemic countries of Africa: from evidence to action. *Am J Trop Med Hyg* **71**, 25-34.

Crompton DW & Nesheim MC (2002) Nutritional impact of intestinal helminthiasis during the human life cycle. *Annu Rev Nutr* **22**, 35-59.

Cummings H, Beyer L, MacDonald C & Bhanjee T (2004) An assessment of the distribution of benefits among program participants with different levels of assets: Micronutrient and Health project Ethiopia and Malawi. Guelph, Canada: University of Guelph.

Cusick SE, Tielsch JM, Ramsan M, Jape JK, Sazawal S, Black RE & Stoltzfus RJ (2005) Short-term effects of vitamin A and antimalarial treatment on erythropoiesis in severely anemic Zanzibari preschool children. *Am J Clin Nutr* **82**, 406-412.

Custodio E, Descalzo MA, Roche J, Sanchez I, Molina L, Lwanga M, Bernis C, Villamor E & Baylin A (2008) Nutritional status and its correlates in Equatorial Guinean preschool children: results from a nationally representative survey. *Food Nutr Bull* **29**, 49-58.

Dane AV & Schneider BH (1998) Program integrity in primary and early secondary prevention: are implementation effects out of control? *Clin Psychol Rev* **18**, 23-45.

De Benoist B, McLean E, Egli I & Cogswell M (2008) Worldwide prevalence of anaemia 1993-2005: WHO global database on anaemia. Geneva, Switzerland: WHO.

De Onis M, Onyango AW, Borghi E, Garza C & Yang H (2006) Comparison of the World Health Organization (WHO) Child Growth Standards and the National Center for Health Statistics/WHO international growth reference: Implications for child health programmes. *Public Health Nutrition* **9**, 942-947.

De Silva N (2003) Impact of mass chemotherapy on the morbidity due to soil-transmitted nematodes. *Acta Trop* **86**, 197-214.

Deaton A (1997) The analysis of household surveys: a microeconometric approach to development policy. Baltimore, Maryland: Johns Hopkins University Press.

Delacollette C, Van der Stuyft P & Molima K (1996) Using community health workers for malaria control: experience in Zaire. *Bull World Health Organ* **74**, 423-430.

Denic S & Agarwal MM (2007) Nutritional iron deficiency: an evolutionary perspective. *Nutrition* **23**, 603-614.

Deribew A, Alemseged F, Birhanu Z, Sena L, Tegegn A, Zeynudin A, Dejene T, Sudhakar M, Abdo N & Tessema F (2010) Effect of training on the use of long-lasting insecticide-treated bed nets on the burden of malaria among vulnerable groups, south-west Ethiopia: baseline results of a cluster randomized trial. *Malar J* **9**, 121.

Desai MR, Terlouw DJ, Kwena AM, Phillips-Howard PA, Kariuki SK, Wannemuehler KA, Odhacha A, Hawley WA, Shi YP, Nahlen BL & Ter Kuile FO (2005) Factors associated with hemoglobin concentrations in pre-school children in Western Kenya: cross-sectional studies. *Am J Trop Med Hyg* **72**, 47-59.

Dewey K & Huffman SL (2009) Maternal, infant, and young child nutrition: combining efforts to maximize impacts on child growth and micronutrient status. *Food Nutr Bull* **30**, S187-S189.

Dewey KG, Yang Z & Boy E (2009) Systematic review and meta-analysis of home fortification of complementary foods. *Matern Child Nutr* **5**, 283-321.

Dicko A, Sagara I, Sissoko MS, Guindo O, Diallo AI, Kone M, Toure OB, Sacko M & Doumbo OK (2008) Impact of intermittent preventive treatment with sulphadoxine-pyrimethamine targeting the transmission season on the incidence of clinical malaria in children in Mali. *Malar J* **7**, 123.

Domellof M, Lonnerdal B, Abrams SA & Hernell O (2002) Iron absorption in breast-fed infants: effects of age, iron status, iron supplements, and complementary foods. *Am J Clin Nutr* **76**, 198-204.

Dossa RA, Ategbo EA, Van Raaij JM, de Graaf C & Hautvast JG (2001) Multivitamin-multimineral and iron supplementation did not improve appetite of young stunted and anemic Beninese children. *J Nutr* **131**, 2874-2879.

Drakeley CJ, Carneiro I, Reyburn H, Malima R, Lusingu JP, Cox J, Theander TG, Nkya WM, Lemnge MM & Riley EM (2005) Altitude-dependent and -independent variations in Plasmodium falciparum prevalence in northeastern Tanzania. *J Infect Dis* **191**, 1589-1598.

DuBois S & Kearney DJ (2005) Iron-deficiency anemia and Helicobacter pylori infection: a review of the evidence. *Am J Gastroenterol* **100**, 453-459.

Dutra-de-Oliveira JE, Lamounier JA, Nogueira de Almeida CA & Marchini JS (2007) Fortification of drinking water to control iron deficiency anemia in preschool children. *Food Nutr Bull* **28**, 173-180.

Ehrhardt S, Burchard GD, Mantel C, Cramer JP, Kaiser S, Kubo M, Otchwemah RN, Bienzle U & Mockenhaupt FP (2006) Malaria, anemia, and malnutrition in African children--defining intervention priorities. *J Infect Dis* **194**, 108-114.

Ekvall H (2003) Malaria and anaemia. *Current Opinion in Hematology* **10**, 108-114.

Ekvall H, Premji Z & Bjorkman A (2000) Micronutrient and iron supplementation and effective antimalarial treatment synergistically improve childhood anaemia. *Trop Med Int Health* **5**, 696-705.

Eliades MJ, Wolkon A, Morgah K, Crawford SB, Dorkenoo A, Sodahlon Y, Hawley WA, Hightower AW, Kuile FO & Terlouw DJ (2006) Burden of malaria at community level in children less than 5 years of age in Togo. *Am J Trop Med Hyg* **75**, 622-629.

Ezeamama AE, McGarvey ST, Acosta LP, Zierler S, Manalo DL, Wu HW, Kurtis JD, Mor V, Olveda RM & Friedman JF (2008) The synergistic effect of concomitant schistosomiasis, hookworm, and trichuris infections on children's anemia burden. *PLoS Negl Trop Dis* **2**, e245.

Faber M, Jogessar VB & Benade AJ (2001) Nutritional status and dietary intakes of children aged 2-5 years and their caregivers in a rural South African community. *Int J Food Sci Nutr* **52**, 401-411.

Faber M, Kvalsvig JD, Lombard CJ & Benade AJ (2005) Effect of a fortified maize-meal porridge on anemia, micronutrient status, and motor development of infants. *Am J Clin Nutr* **82**, 1032-1039.

Fairbanks VF (1999) Iron in Medicine and Nutrition. In *Modern Nutrition in Health and Disease* [ME Shils, JA Olson, M Shike and AC Ross, editors]. Pennsylvania: Williams & Wilkins.

FAO/WHO (1988) Requirements of vitamin A, iron, folate and vitamin B12. Rome: Food and Agricultural Organization.

Feikin DR, Nguyen LM, Adazu K, Ombok M, Audi A, Slutsker L & Lindblade KA (2009) The impact of distance of residence from a peripheral health facility on pediatric health utilisation in rural western Kenya. *Trop Med Int Health* **14**, 54-61.

Ferguson EL, Gibson RS, Opare-Obisaw C, Ounpuu S, Thompson LU & Lehrfeld J (1993) The zinc nutriture of preschool children living in two African countries. *J Nutr* **123**, 1487-1496.

Fernald LC, Gertler PJ & Neufeld LM (2008) Role of cash in conditional cash transfer programmes for child health, growth, and development: an analysis of Mexico's Oportunidades. *Lancet* **371**, 828-837.

Filmer D & Pritchett LH (2001) Estimating wealth effects without expenditure data--or tears: an application to educational enrollments in states of India. *Demography* **38**, 115-132.

Fischer Walker C & Black RE (2004) Zinc and the risk for infectious disease. *Annu Rev Nutr* **24**, 255-275.

Fischer Walker C, Kordas K, Stoltzfus RJ & Black RE (2005) Interactive effects of iron and zinc on biochemical and functional outcomes in supplementation trials. *Am J Clin Nutr* **82**, 5-12.

Fishman SM, Christian P & West KP (2000) The role of vitamins in the prevention and control of anaemia. *Public Health Nutr* **3**, 125-150.

Fotso JC & Kuate-Defo B (2006) Household and community socioeconomic influences on early childhood malnutrition in Africa. *J Biosoc Sci* **38**, 289-313.

Friedman JF, Kanzaria HK & McGarvey ST (2005a) Human schistosomiasis and anemia: the relationship and potential mechanisms. *Trends Parasitol* **21**, 386-392.

Friedman JF, Kwena AM, Mirel LB, Kariuki SK, Terlouw DJ, Phillips-Howard PA, Hawley WA, Nahlen BL, Shi YP & ter Kuile FO (2005b) Malaria and nutritional status among pre-school children: results from cross-sectional surveys in western Kenya. *Am J Trop Med Hyg* **73**, 698-704.

Friis H, Mwaniki D, Omondi B, Muniu E, Magnussen P, Geissler W, Thiong'o F & Michaelsen KF (1997) Serum retinol concentrations and Schistosoma mansoni,

intestinal helminths, and malarial parasitemia: a cross-sectional study in Kenyan preschool and primary school children. *Am J Clin Nutr* **66**, 665-671.

Gakidou E, Oza S, Vidal Fuertes C, Li AY, Lee DK, Sousa A, Hogan MC, Vander Hoorn S & Ezzati M (2007) Improving child survival through environmental and nutritional interventions: the importance of targeting interventions toward the poor. *JAMA* **298**, 1876-1887.

Galea S, Ahern J & Karpati A (2005) A model of underlying socioeconomic vulnerability in human populations: evidence from variability in population health and implications for public health. *Soc Sci Med* **60**, 2417-2430.

Garba A, Barkire N, Djibo A, Lamine MS, Sofo B, Gouvras AN, Bosque-Oliva E, Webster JP, Stothard JR, Utzinger J & Fenwick A (2010) Schistosomiasis in infants and preschool-aged children: Infection in a single Schistosoma haematobium and a mixed S. haematobium-S. mansoni foci of Niger. *Acta Trop*.

Gardiner C, Biggar RJ, Collins WE & Nkrumah FK (1984) Malaria in urban and rural areas of southern Ghana: a survey of parasitaemia, antibodies, and antimalarial practices. *Bull World Health Organ* **62**, 607-613.

Geerligs PD, Brabin BJ & Omari AA (2003) Food prepared in iron cooking pots as an intervention for reducing iron deficiency anaemia in developing countries: a systematic review. *J Hum Nutr Diet* **16**, 275-281.

Gera T, Sachdev HP & Nestel P (2009) Effect of combining multiple micronutrients with iron supplementation on Hb response in children: systematic review of randomized controlled trials. *Public Health Nutr* **12**, 756-773.

Gera T, Sachdev HP, Nestel P & Sachdev SS (2007) Effect of iron supplementation on haemoglobin response in children: systematic review of randomised controlled trials. *J Pediatr Gastroenterol Nutr* **44**, 468-486.

Gertler PJ (2004) Do conditional cash transfers improve child health? Evidence from PROGRESA's control randomized experiment. *American economic review* **94**, 336-341.

Gessner BD, Chimonas MA & Grady SC (2010) It takes a village: community education predicts paediatric lower-respiratory infection risk better than maternal education. *J Epidemiol Community Health* **64**, 130-135.

Ghana Health Service (1995) National Anaemia Prevalence Survey. Accra, Ghana: Nutrition Unit, Ghana Health Services.

Ghana Statistical Service (2002) Ghana 2000 Population and Housing Census. Accra, Ghana: Ghana Statistical Service.

Ghana Statistical Service (GSS), Ghana Health Service (GHS) & ICF Macro (2009) Ghana Demographic and Health Survey 2008. Accra, Ghana: GSS, GHS, and ICF Macro.

Ghana Statistical Service (GSS), Noguchi Memorial Institute for Medical Research (NMIMR) & ORC Macro (2004) Ghana Demographic and Health Survey 2003. Calverton, Maryland: GSS, NMIMR, and ORC Macro.

Gibson RS (2005) *Principles of Nutritional Assessment*, 2nd ed. New York: Oxford University Press.

Gibson RS, Ferguson EL & Lehrfeld J (1998) Complementary foods for infant feeding in developing countries: their nutrient adequacy and improvement. *Eur J Clin Nutr* **52**, 764-770.

Gibson RS & Hotz C (2001) Dietary diversification/modification strategies to enhance micronutrient content and bioavailability of diets in developing countries. *Br J Nutr* **85 Suppl 2**, S159-166.

Gibson RS, Yeudall F, Drost N, Mtitimuni BM & Cullinan TR (2003) Experiences of a community-based dietary intervention to enhance micronutrient adequacy of diets low in animal source foods and high in phytate: a case study in rural Malawian children. *J Nutr* **133**, 3992S-3999S.

Gillespie S & Allen L (2002) What works, and what really works. *Public Health Nutr* **5**, 513-514.

Gillespie S & Johnston JL (1998) Expert consultation on anaemia determinants and interventions. Ottawa: Micronutrient Initiative.

Gittelsohn J & Vastine AE (2003) Sociocultural and household factors impacting on the selection, allocation and consumption of animal source foods: current knowledge and application. *J Nutr* **133**, 4036S-4041S.

Grabowsky M, Farrell N, Hawley W, Chimumbwa J, Hoyer S, Wolkon A & Selanikio J (2005) Integrating insecticide-treated bednets into a measles vaccination campaign achieves high, rapid and equitable coverage with direct and voucher-based methods. *Trop Med Int Health* **10**, 1151-1160.

Grabowsky M, Nobiya T & Selanikio J (2007) Sustained high coverage of insecticide-treated bednets through combined Catch-up and Keep-up strategies. *Trop Med Int Health* **12**, 815-822.

Greenland S (2004) Model-based estimation of relative risks and other epidemiologic measures in studies of common outcomes and in case-control studies. *Am J Epidemiol* **160**, 301-305.

Gulani A, Nagpal J, Osmond C & Sachdev HP (2007) Effect of administration of intestinal anthelmintic drugs on haemoglobin: systematic review of randomised controlled trials. *BMJ* **334**, 1095.

Guyatt HL, Brooker S, Kihamia CM, Hall A & Bundy DA (2001) Evaluation of efficacy of school-based anthelmintic treatments against anaemia in children in the United Republic of Tanzania. *Bull World Health Organ* **79**, 695-703.

Guyon AB, Quinn VJ, Hainsworth M, Ravonimanantsoa P, Ravelojoana V, Rambeloson Z & Martin L (2009) Implementing an integrated nutrition package at large scale in Madagascar: the Essential Nutrition Actions framework. *Food Nutr Bull* **30**, 233-244.

Haas JD, Beard JL, Murray-Kolb LE, del Mundo AM, Felix A & Gregorio GB (2005) Iron-biofortified rice improves the iron stores of nonanemic Filipino women. *J Nutr* **135**, 2823-2830.

Haas JD & Brownlie Tt (2001) Iron deficiency and reduced work capacity: a critical review of the research to determine a causal relationship. *J Nutr* **131**, 676S-688S; discussion 688S-690S.

Haddad L, Alderman H, Appleton S, Song L & Yohannes Y (2003) Reducing child malnutrition: how far does income growth take us? *The World Bank Economic Review* **17**, 107-131.

Haematology) IICfSi (1987) Recommendations for reference method for haemoglobinometry in human blood and specifications for international

haemoglobin-cyanide reference preparation (3rd edition). *Clinical and Laboratory Haematology* **9**, 73-79.

Haldar K & Mohandas N (2009) Malaria, erythrocytic infection, and anemia. *Hematology Am Soc Hematol Educ Program*, 87-93.

Hall A, Hewitt G, Tuffrey V & de Silva N (2008) A review and meta-analysis of the impact of intestinal worms on child growth and nutrition. *Maternal & Child Nutrition* **4**, 118-236.

Hallberg L, Hoppe M, Andersson M & Hulthen L (2003) The role of meat to improve the critical iron balance during weaning. *Pediatrics* **111**, 864-870.

Hartgers FC, Obeng BB, Kruize YC, Dijkhuis A, McCall M, Sauerwein RW, Luty AJ, Boakye DA & Yazdanbakhsh M (2009) Responses to malarial antigens are altered in helminth-infected children. *J Infect Dis* **199**, 1528-1535.

Hassan K, Sullivan KM, Yip R & Woodruff BA (1997) Factors associated with anemia in refugee children. *J Nutr* **127**, 2194-2198.

Hawe P, Shiell A, Riley T & Gold L (2004) Methods for exploring implementation variation and local context within a cluster randomised community intervention trial. *J Epidemiol Community Health* **58**, 788-793.

Heikens GT, Amadi BC, Manary M, Rollins N & Tomkins A (2008) Nutrition interventions need improved operational capacity. *Lancet* **371**, 181-182.

Holtz TH, Kachur SP, Marum LH, Mkandala C, Chizani N, Roberts JM, Macheso A & Parise ME (2003) Care seeking behaviour and treatment of febrile illness in children aged less than five years: a household survey in Blantyre District, Malawi. *Trans R Soc Trop Med Hyg* **97**, 491-497.

Hong R (2007) Effect of economic inequality on chronic childhood undernutrition in Ghana. *Public Health Nutr* **10**, 371-378.

Horton S, Alderman H & J R (2008) Copenhagen Consensus 2008 Challenge Paper: Hunger and Malnutrition. Copenhagen: Copenhagen Consensus Center.

Horton S & Ross J (2003) The economics of iron deficiency. *Food Policy* **28**, 51-75.

Houweling TA, Kunst AE & Mackenbach JP (2003) Measuring health inequality among children in developing countries: does the choice of the indicator of economic status matter? *Int J Equity Health* **2**, 8.

Howard CT, de Pee S, Sari M, Bloem MW & Semba RD (2007) Association of diarrhea with anemia among children under age five living in rural areas of Indonesia. *J Trop Pediatr* **53**, 238-244.

Howard J & Davies SC (2007) Haemoglobinopathies. *Paediatrics and Child Health* **17**, 311-316.

Howe LD, Hargreaves JR & Huttly SR (2008) Issues in the construction of wealth indices for the measurement of socio-economic position in low-income countries. *Emerg Themes Epidemiol* **5**, 3.

Hugman A (2006) Hepcidin: an important new regulator of iron homeostasis. *Clin Lab Haematol* **28**, 75-83.

Humberg A, Kammer J, Mordmuller B, Kremsner PG & Lell B (2011) Haematological and biochemical reference intervals for infants and children in Gabon. *Trop Med Int Health* **16**, 343-348.

Hurrell R (2002) How to ensure adequate iron absorption from iron-fortified food. *Nutr Rev* **60**, S7-15; discussion S43.

Hurrell RF (2004) Improved technologies enhance the efficacy of food iron fortification. *Int J Vitam Nutr Res* **74**, 385.

Hurtado EK, Claussen AH & Scott KG (1999) Early childhood anemia and mild or moderate mental retardation. *Am J Clin Nutr* **69**, 115-119.

Iannotti LL, Tielsch JM, Black MM & Black RE (2006) Iron supplementation in early childhood: health benefits and risks. *Am J Clin Nutr* **84**, 1261-1276.

INACG (1999) INACG Consensus Statement. Safety of iron supplementation programs in malaria-endemic regions. Washington: ILSI.

IOM (2001) Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington, DC.

Ip H, Hyder SM, Haseen F, Rahman M & Zlotkin SH (2009) Improved adherence and anaemia cure rates with flexible administration of micronutrient Sprinkles: a new public health approach to anaemia control. *Eur J Clin Nutr* **63**, 165-172.

Isanaka S, Duggan C & Fawzi WW (2009) Patterns of postnatal growth in HIV-infected and HIV-exposed children. *Nutr Rev* **67**, 343-359.

Jackson AA (2007) Anemia in severe undernutrition (malnutrition). In *Nutritional Anemia* [K Kraemer and MB Zimmerman, editors]. Basel, Switzerland: SIGHT AND LIFE.

Jackson N & Waters E (2005) Criteria for the systematic review of health promotion and public health interventions. *Health Promot Int* **20**, 367-374.

Jimenez C, Leets I, Puche R, Anzola E, Montilla R, Parra C, Aguilera A & Garcia-Casal MN (2010) A single dose of vitamin A improves haemoglobin concentration, retinol status and phagocytic function of neutrophils in preschool children. *Br J Nutr* **103**, 798-802.

Joseph AE & Poyner A (1982) Interpreting patterns of public service utilization in rural areas. *Economic Geography* **58**, 262-273.

Kahigwa E, Schellenberg D, Sanz S, Aponte JJ, Wigayi J, Mshinda H, Alonso P & Menendez C (2002) Risk factors for presentation to hospital with severe anaemia in Tanzanian children: a case-control study. *Trop Med Int Health* **7**, 823-830.

Kahn HA (1983) *An introduction to epidemiologic methods*. New York: Oxford University Press.

Kapur D, Sharma S & Agarwal KN (2003) Effectiveness of nutrition education, iron supplementation or both on iron status in children. *Indian Pediatr* **40**, 1131-1144.

Kariger PK, Stoltzfus RJ, Olney DK, Sazawal S, Black R, Tielsch JM, Frongillo EA, Khalfan SS & Pollitt E (2005) Iron deficiency and physical growth predict attainment of walking but not crawling in poorly nourished Zanzibari infants. *J Nutr* **135**, 814-819.

Kibona N, Doland C, Watson FE, Alnwick D & Tomkins AM (1995) An evaluation of a project to improve child nutrition in Tanzania. *International Journal of Food Sciences and Nutrition* **46**, 233-239.

Kidane G & Morrow RH (2000) Teaching mothers to provide home treatment of malaria in Tigray, Ethiopia: a randomised trial. *Lancet* **356**, 550-555.

Kitua AY, Smith TA, Alonso PL, Urassa H, Masanja H, Kimario J & Tanner M (1997) The role of low level Plasmodium falciparum parasitaemia in anaemia among

infants living in an area of intense and perennial transmission. *Trop Med Int Health* **2**, 325-333.

Kleinschmidt I, Schwabe C, Benavente L, Torrez M, Ridl FC, Segura JL, Ehmer P & Nchama GN (2009) Marked increase in child survival after four years of intensive malaria control. *Am J Trop Med Hyg* **80**, 882-888.

Klinkenberg E, McCall PJ, Wilson MD, Akoto AO, Amerasinghe FP, Bates I, Verhoeff FH, Barnish G & Donnelly MJ (2006) Urban malaria and anaemia in children: a cross-sectional survey in two cities of Ghana. *Trop Med Int Health* **11**, 578-588.

Koram KA, Owusu-Agyei S, Fryauff DJ, Anto F, Atuguba F, Hodgson A, Hoffman SL & Nkrumah FK (2003) Seasonal profiles of malaria infection, anaemia, and bednet use among age groups and communities in northern Ghana. *Trop Med Int Health* **8**, 793-802.

Korenromp EL, Armstrong-Schellenberg JR, Williams BG, Nahlen BL & Snow RW (2004) Impact of malaria control on childhood anaemia in Africa -- a quantitative review. *Trop Med Int Health* **9**, 1050-1065.

Koury MJ & Ponka P (2004) New insights into erythropoiesis: the roles of folate, vitamin B12, and iron. *Annu Rev Nutr* **24**, 105-131.

Lartey A, Manu A, Brown KH, Peerson JM & Dewey KG (1999) A randomized, community-based trial of the effects of improved, centrally processed complementary foods on growth and micronutrient status of Ghanaian infants from 6 to 12 mo of age. *American Journal of Clinical Nutrition* **70**, 391-404.

Lechtig A, Cornale G, Ugaz ME & Arias L (2009) Decreasing stunting, anemia, and vitamin A deficiency in Peru: results of the Good Start in Life Program. *Food Nutr Bull* **30**, 37-48.

Lell B, May J, Schmidt-Ott RJ, Lehman LG, Luckner D, Greve B, Matousek P, Schmid D, Herbich K, Mockenhaupt FP, Meyer CG, Bienzle U & Kremsner PG (1999) The role of red blood cell polymorphisms in resistance and susceptibility to malaria. *Clin Infect Dis* **28**, 794-799.

Lengeler C (2004) Insecticide-treated bed nets and curtains for preventing malaria. *Cochrane Database Syst Rev*, CD000363.

Leroy JL & Frongillo EA (2007) Can interventions to promote animal production ameliorate undernutrition? *J Nutr* **137**, 2311-2316.

Leroy JL, Ruel MT & Verhofstadt E (2009) The impact of conditional cash transfer programmes on child nutrition: a review of evidence using a programme theory framework. *Journal of Development Effectiveness* **1**, 103-129.

Lin CA, Boslaugh S, Ciliberto HM, Maleta K, Ashorn P, Briend A & Manary MJ (2007) A prospective assessment of food and nutrient intake in a population of Malawian children at risk for kwashiorkor. *J Pediatr Gastroenterol Nutr* **44**, 487-493.

Lindquist K (n.d.) How can I estimate relative risk using glm for common outcomes in cohort studies?: UCLA: Academic Technology Services, Statistical Consulting Group. Retrieved February 25, 2011, from http://www.ats.ucla.edu/stat/stata/faq/relative_risk.htm.

Link BG & Phelan J (1995) Social conditions as fundamental causes of disease. *J Health Soc Behav* **Spec No**, 80-94.

Loechl CU, Menon P, Arimond M, Ruel MT, Pelto G, Habicht JP & Michaud L (2009) Using programme theory to assess the feasibility of delivering micronutrient Sprinkles through a food-assisted maternal and child health and nutrition programme in rural Haiti. *Matern Child Nutr* **5**, 33-48.

Lopez de Romana G (2000) Experience with complementary feeding in the FONCODES project. *Food Nutr Bull* **21**, 43-48.

Lopriore C, Guidoum Y, Briend A & Branca F (2004) Spread fortified with vitamins and minerals induces catch-up growth and eradicates severe anemia in stunted refugee children aged 3-6 y. *Am J Clin Nutr* **80**, 973-981.

Low JW, Arimond M, Osman N, Cunguara B, Zano F & Tschirley D (2007) A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique. *J Nutr* **137**, 1320-1327.

Lozoff B (2007) Iron deficiency and child development. *Food Nutr Bull* **28**, S560-571.

Lozoff B, Corapci F, Burden MJ, Kaciroti N, Angulo-Barroso R, Sazawal S & Black M (2007) Preschool-aged children with iron deficiency anemia show altered affect and behavior. *J Nutr* **137**, 683-689.

Lusingu JP, Vestergaard LS, Mmbando BP, Drakeley CJ, Jones C, Akida J, Savaeli ZX, Kitua AY, Lemnge MM & Theander TG (2004) Malaria morbidity and immunity among residents of villages with different Plasmodium falciparum transmission intensity in North-Eastern Tanzania. *Malar J* **3**, 26.

Lutter CK (2008) Iron deficiency in young children in low-income countries and new approaches for its prevention. *J Nutr* **138**, 2523-2528.

Lutter CK & Rivera JA (2003) Nutritional status of infants and young children and characteristics of their diets. *J Nutr* **133**, 2941S-2949S.

Lutter CK, Rodriguez A, Fuenmayor G, Avila L, Sempertegui F & Escobar J (2008) Growth and micronutrient status in children receiving a fortified complementary food. *J Nutr* **138**, 379-388.

Lyke KE, Dicko A, Dabo A, Sangare L, Kone A, Coulibaly D, Guindo A, Traore K, Daou M, Diarra I, Sztein MB, Plowe CV & Doumbo OK (2005) Association of Schistosoma haematobium infection with protection against acute Plasmodium falciparum malaria in Malian children. *Am J Trop Med Hyg* **73**, 1124-1130.

Lynch MF, Griffin IJ, Hawthorne KM, Chen Z, Hamzo MG & Abrams SA (2007a) Iron absorption is more closely related to iron status than to daily iron intake in 12- to 48-mo-old children. *J Nutr* **137**, 88-92.

Lynch S, Stoltzfus R & Rawat R (2007b) Critical review of strategies to prevent and control iron deficiency in children. *Food Nutr Bull* **28**, S610-620.

MacDonald C, Mildon A, Neequaye M, Namarika R & Yiannakis M (2007) Anemia - can its widespread prevalence among women in developing countries be impacted? A case study: effectiveness of a large-scale, multiple-intervention nutrition program on decreasing anemia in Ghanaian and Malawian women. In *Women's Health in the Majority World: Issues and Initiatives* [L Elit and J Chamberlain, editors]. New York: Nova Science Publishers.

Mafiana CF, Ekpo UF & Ojo DA (2003) Urinary schistosomiasis in preschool children in settlements around Oyan Reservoir in Ogun State, Nigeria: implications for control. *Trop Med Int Health* **8**, 78-82.

Magnani R (1997) Sampling Guide. Washington DC: Food and Nutrition Technical Assistance Project (FANTA).

Makoka D (2009) Towards an understanding of regional disparities in social inequities in maternal health in Malawi. *African Health Sciences* **9**, 234-241.

Malamba S, Hladik W, Reingold A, Banage F, McFarland W, Rutherford G, Mimbe D, Nzaro E, Downing R & Mermin J (2007) The effect of HIV on morbidity and mortality in children with severe malarial anaemia. *Malar J* **6**, 143.

Malawi National Statistical Office & International Food Policy Research Institute (2002) Malawi: an atlas of social statistics. Zomba, Malawi: National Statistical Office.

Malawi National Vulnerability Assessment Committee (2005) Malawi Baseline Livelihood Profiles: Malawi National Vulnerability Assessment Committee and SADC FANR Vulnerability Assessment Committee.

Malhotra I, Dent A, Mungai P, Wamachi A, Ouma JH, Narum DL, Muchiri E, Tisch DJ & King CL (2009) Can prenatal malaria exposure produce an immune tolerant phenotype? A prospective birth cohort study in Kenya. *PLoS Med* **6**, e1000116.

Maluccio JA & Flores R (2004) Impact evaluation of a conditional cash transfer program: the Nicaraguan Red de Proteccion Social. In *FCND Discussion Paper 184*. Washington, DC: International Food Policy Research Institute.

Manjrekar RR (1999) Evaluation of the integrated management of childhood illness guidelines for treatment of intestinal helminth infections in sick children 2-4 years, western Kenya, Emory University.

Martorell R (1999) The nature of child malnutrition and its long-term implications. *Food Nutr Bull* **20**, 288-292.

Martorell R & Ho TJ (1984) Malnutrition, morbidity and mortality. *Population and Development Review* **10**, 49-68.

Masanja H, de Savigny D, Smithson P, Schellenberg J, John T, Mbuya C, Upunda G, Boerma T, Victora C, Smith T & Mshinda H (2008) Child survival gains in Tanzania: analysis of data from demographic and health surveys. *Lancet* **371**, 1276-1283.

Masmas TN, Garly ML, Lisse IM, Rodriques A, Petersen PT & Birgens H (2006) Inherited hemoglobin disorders in Guinea-Bissau, West Africa: a population study. *Hemoglobin* **30**, 355-364.

Mathanga DP, Campbell CH, Jr., Vanden Eng J, Wolkon A, Bronzan RN, Malenga GJ, Ali D & Desai M (2010) Comparison of anaemia and parasitaemia as indicators of malaria control in household and EPI-health facility surveys in Malawi. *Malar J* **9**, 107.

McClung JP & Karl JP (2009) Iron deficiency and obesity: the contribution of inflammation and diminished iron absorption. *Nutr Rev* **67**, 100-104.

MCE (2003) Multi-Country Evaluation of IMCI Effectiveness, Cost and Impact: data synthesis in the MCE-Tanzania. Kingham, Cotswolds: WHO. Retrieved March 13, 2011 from http://www.who.int/imci-mce/Publications/Kingham_MR.pdf.

McElroy PD, Lal AA, Hawley WA, Bloland PB, Kuile FO, Oloo AJ, Harlow SD, Lin X & Nahlen BL (1999) Analysis of repeated hemoglobin measures in full-term, normal birth weight Kenyan children between birth and four years of age. III. The Asemobo Bay Cohort Project. *Am J Trop Med Hyg* **61**, 932-940.

McElroy PD, ter Kuile FO, Lal AA, Bloland PB, Hawley WA, Oloo AJ, Monto AS, Meshnick SR & Nahlen BL (2000) Effect of Plasmodium falciparum parasitemia density on hemoglobin concentrations among full-term, normal birth weight children in western Kenya, IV. The Asembo Bay Cohort Project. *Am J Trop Med Hyg* **62**, 504-512.

McLaren L, Ghali LM, Lorenzetti D & Rock M (2007) Out of context? Translating evidence from the North Karelia project over place and time. *Health Educ Res* **22**, 414-424.

McLean E, de Benoist B & Allen LH (2008) Review of the magnitude of folate and vitamin B12 deficiencies worldwide. *Food Nutr Bull* **29**, S38-51.

McLean E, Egli I, Cogswell M, de Benoist B & Wojdyla D (2007) Worldwide prevalence of anemia in preschool aged children, pregnant women and non-pregnant women of reproductive age. In *Nutritional Anemia* [K Kraemer and MB Zimmerman, editors]. Basel: SIGHT AND LIFE Press.

McNutt LA, Wu C, Xue X & Hafner JP (2003) Estimating the relative risk in cohort studies and clinical trials of common outcomes. *Am J Epidemiol* **157**, 940-943.

Mebrahtu T, Stoltzfus RJ, Chwaya HM, Jape JK, Savioli L, Montresor A, Albonico M & Tielsch JM (2004) Low-dose daily iron supplementation for 12 months does not increase the prevalence of malarial infection or density of parasites in young Zanzibari children. *J Nutr* **134**, 3037-3041.

Mehta S, Giovannucci E, Mugusi FM, Spiegelman D, Aboud S, Hertzmark E, Msamanga GI, Hunter D & Fawzi WW (2010) Vitamin D status of HIV-infected women and its association with HIV disease progression, anemia, and mortality. *PLoS One* **5**, e8770.

Mejia LA & Chew F (1988) Hematological effect of supplementing anemic children with vitamin A alone and in combination with iron. *Am J Clin Nutr* **48**, 595-600.

Menendez C, Kahigwa E, Hirt R, Vounatsou P, Aponte JJ, Font F, Acosta CJ, Schellenberg DM, Galindo CM, Kimario J, Urassa H, Brabin B, Smith TA, Kitua AY, Tanner M & Alonso PL (1997) Randomised placebo-controlled trial of iron supplementation and malaria chemoprophylaxis for prevention of severe anaemia and malaria in Tanzanian infants. *Lancet* **350**, 844-850.

Menon P, Ruel MT, Loechl CU, Arimond M, Habicht JP, Pelto G & Michaud L (2007a) Micronutrient Sprinkles reduce anemia among 9- to 24-mo-old children when delivered through an integrated health and nutrition program in rural Haiti. *J Nutr* **137**, 1023-1030.

Menon P, Ruel MT, Loechl CU, Arimond M, Habicht JP, Pelto G & Michaud L (2007b) Micronutrient Sprinkles reduce anemia among 9- to 24-mo-old children when delivered through an integrated health and nutrition program in rural Haiti. *Journal of Nutrition* **137**, 1023-1030.

Mensah P & Tomkins A (2003) Household-level technologies to improve the availability and preparation of adequate and safe complementary foods. *Food Nutr Bull* **24**, 104-125.

Meremikwu MM, Omari AA & Garner P (2005) Chemoprophylaxis and intermittent treatment for preventing malaria in children. *Cochrane Database Syst Rev*, CD003756.

Metz J (2007) Folic acid metabolism and malaria. *Food Nutr Bull* **28**, S540-549.

Metz J (2008) A high prevalence of biochemical evidence of vitamin B12 or folate deficiency does not translate into a comparable prevalence of anemia. *Food Nutr Bull* **29**, S74-85.

Miller MF, Humphrey JH, Iliff PJ, Malaba LC, Mbuya NV & Stoltzfus RJ (2006) Neonatal erythropoiesis and subsequent anemia in HIV-positive and HIV-negative Zimbabwean babies during the first year of life: a longitudinal study. *BMC Infect Dis* **6**, 1.

Mmbando BP, Vestergaard LS, Kitua AY, Lemnge MM, Theander TG & Lusingu JP (2010) A progressive declining in the burden of malaria in north-eastern Tanzania. *Malar J* **9**, 216.

Mockenhaupt FP, Bienzle U, May J, Falusi AG, Ademowo OG, Olumese PE & Meyer CG (1999) Plasmodium falciparum infection: influence on hemoglobin levels in alpha-thalassemia and microcytosis. *J Infect Dis* **180**, 925-928.

Mockenhaupt FP, Ehrhardt S, Gellert S, Otchwemah RN, Dietz E, Anemana SD & Bienzle U (2004) Alpha(+)-thalassemia protects African children from severe malaria. *Blood* **104**, 2003-2006.

Mogensen CB, Sorensen JE & Bjorkman A (2006) Pallor as a sign of anaemia in small Tanzanian children at different health care levels. *Acta Trop* **99**, 113-118.

MOHP (2003) Report of the national micronutrient survey 2001. Lilongwe, Malawi: Ministry of Health and Population.

Mora JO (2002) Iron supplementation: overcoming technical and practical barriers. *J Nutr* **132**, 853S-855S.

Mora JO (2007) Integrated Anemia Control Strategy (IACS) has significantly reduced anemia in women and children in Nicaragua. Ottawa, Canada: Micronutrient Initiative.

Mosley WH & Chen LC (1984) An analytical framework for the study of child survival in developing countries. *Population and Development Review* **10 Suppl**, 25-45.

Mulholland K (2005) Commentary: comorbidity as a factor in child health and child survival in developing countries. *Int J Epidemiol* **34**, 375-377.

Muller O, Jahn A & von Braun J (2002) Micronutrient supplementation for malaria control--hype or hope? *Trop Med Int Health* **7**, 1-3.

Munday S (2007) Review of intermittent preventive treatment for malaria in infants and children. *J Paediatr Child Health* **43**, 424-428.

Munoz EC, Rosado JL, Lopez P, Furr HC & Allen LH (2000) Iron and zinc supplementation improves indicators of vitamin A status of Mexican preschoolers. *Am J Clin Nutr* **71**, 789-794.

Murphy SC & Breman JG (2001) Gaps in the childhood malaria burden in Africa: cerebral malaria, neurological sequelae, anemia, respiratory distress, hypoglycemia, and complications of pregnancy. *Am J Trop Med Hyg* **64**, 57-67.

Mushi AK, Schellenberg JR, Mponda H & Lengeler C (2003) Targeted subsidy for malaria control with treated nets using a discount voucher system in Tanzania. *Health Policy Plan* **18**, 163-171.

Muula AS, Polycarpe MY, Job J, Siziya S & Rudatsikira E (2009) Association between maternal use of traditional healer services and child vaccination coverage in Pont-Sonde, Haiti. *Int J Equity Health* **8**, 1.

Mwanri L, Worsley A, Ryan P & Masika J (2000) Supplemental vitamin A improves anemia and growth in anemic school children in Tanzania. *J Nutr* **130**, 2691-2696.

National Bureau of Statistics (NBS) (2002) United Republic of Tanzania 2002 Population and Housing Census. Dar es Salaam, Tanzania: National Bureau of Statistics.

National Bureau of Statistics Tanzania & ORC Macro (2005) Tanzania Demographic and Health Survey 2004-05. Dar es Salaam, Tanzania: National Bureau of Statistics and ORC Macro.

National Statistical Office (Malawi) (2001) Malawi 1998 Population and Housing Census. Zomba, Malawi: National Statistical Office.

National Statistical Office (Malawi) & ORC Macro (2005) Malawi Demographic and Health Survey 2004. Calverton, Maryland: NSO and ORC Macro.

Ncube TN, Greiner T, Malaba LC & Gebre-Medhin M (2001) Supplementing lactating women with pureed papaya and grated carrots improved vitamin A status in a placebo-controlled trial. *J Nutr* **131**, 1497-1502.

Nemeth E & Ganz T (2006) Regulation of iron metabolism by hepcidin. *Annu Rev Nutr* **26**, 323-342.

Nestel P (2002) Adjusting Hemoglobin Values in Program Surveys. Washington, DC: INACG.

Ngnie-Teta I, Receveur O & Kuate-Defo B (2007) Risk factors for moderate to severe anemia among children in Benin and Mali: insights from a multilevel analysis. *Food Nutr Bull* **28**, 76-89.

Njelekela M, Sato T, Nara Y, Miki T, Kuga S, Noguchi T, Kanda T, Yamori M, Ntogwisangu J, Masesa Z, Mashalla Y, Mtabaji J & Yamori Y (2003) Nutritional variation and cardiovascular risk factors in Tanzania--rural-urban difference. *S Afr Med J* **93**, 295-299.

Noor AM, Mutheu JJ, Tatem AJ, Hay SI & Snow RW (2009) Insecticide-treated net coverage in Africa: mapping progress in 2000-07. *Lancet* **373**, 58-67.

Nussenblatt V & Semba RD (2002) Micronutrient malnutrition and the pathogenesis of malarial anemia. *Acta Trop* **82**, 321-337.

Obonyo CO, Vulule J, Akhwale WS & Grobbee DE (2007) In-hospital morbidity and mortality due to severe malarial anemia in western Kenya. *Am J Trop Med Hyg* **77**, 23-28.

Odogwu SE, Ramamurthy NK, Kabatereine NB, Kazibwe F, Tukahebwa E, Webster JP, Fenwick A & Stothard JR (2006) Schistosoma mansoni in infants (aged < 3 years) along the Ugandan shoreline of Lake Victoria. *Ann Trop Med Parasitol* **100**, 315-326.

Ofori MF, Dodoo D, Staalsoe T, Kurtzhals JA, Koram K, Theander TG, Akanmori BD & Hviid L (2002) Malaria-induced acquisition of antibodies to Plasmodium falciparum variant surface antigens. *Infect Immun* **70**, 2982-2988.

Olivares M, Pizarro F & Ruz M (2007) Zinc inhibits nonheme iron bioavailability in humans. *Biol Trace Elem Res* **117**, 7-14.

Olivares M, Walter T, Hertrampf E, Pizarro F & Stekel A (1989) Prevention of iron deficiency by milk fortification. The Chilean experience. *Acta Paediatr Scand Suppl* **361**, 109-113.

Olney DK, Pollitt E, Kariger PK, Khalfan SS, Ali NS, Tielsch JM, Sazawal S, Black R, Mast D, Allen LH & Stoltzfus RJ (2007) Young Zanzibari children with iron deficiency, iron deficiency anemia, stunting, or malaria have lower motor activity scores and spend less time in locomotion. *J Nutr* **137**, 2756-2762.

Olney DK, Talukder A, Iannotti LL, Ruel MT & Quinn V (2009) Assessing impact and impact pathways of a homestead food production program on household and child nutrition in Cambodia. *Food Nutr Bull* **30**, 355-369.

Ong'echa JM, Keller CC, Were T, Ouma C, Otieno RO, Landis-Lewis Z, Ochiel D, Slingluff JL, Mogere S, Ogonji GA, Orago AS, Vulule JM, Kaplan SS, Day RD & Perkins DJ (2006) Parasitemia, anemia, and malarial anemia in infants and young children in a rural holoendemic Plasmodium falciparum transmission area. *Am J Trop Med Hyg* **74**, 376-385.

ORC Macro (2001) Nutrition of young children and mothers in Tanzania: findings from the 1999 Tanzania Reproductive and Child Health Survey. In *Africa Nutrition Chartbooks*. Calverton, Maryland: ORC Macro.

Osorio MM, Lira PI & Ashworth A (2004) Factors associated with Hb concentration in children aged 6-59 months in the State of Pernambuco, Brazil. *Br J Nutr* **91**, 307-315.

Otieno RO, Ouma C, Ong'echa JM, Keller CC, Were T, Waindi EN, Michaels MG, Day RD, Vulule JM & Perkins DJ (2006) Increased severe anemia in HIV-1-exposed and HIV-1-positive infants and children during acute malaria. *AIDS* **20**, 275-280.

Ouedraogo HZ, Dramaix-Wilmet M, Zeba AN, Hennart P & Donnen P (2008) Effect of iron or multiple micronutrient supplements on the prevalence of anaemia among anaemic young children of a malaria-endemic area: a randomized double-blind trial. *Trop Med Int Health* **13**, 1257-1266.

Pachón H, Simondon KB, Fall ST, Menon P, Ruel MT, Hotz C, Creed-Kanashiro H, Arce B, Liria Dominguez MR, Frongillo EA & Brown DL (2007) Constraints on the delivery of animal-source foods to infants and young children: Case studies from five countries. *Food Nutr Bull* **28**, 215-229.

PAHO/WHO (2003) Guiding principles for complementary feeding of the breastfed child. Washington DC: Pan American Health Organization/World Health Organization.

Palafox NA, Gamble MV, Dancheck B, Ricks MO, Briand K & Semba RD (2003) Vitamin A deficiency, iron deficiency, and anemia among preschool children in the Republic of the Marshall Islands. *Nutrition* **19**, 405-408.

Palupi L, Schultink W, Achadi E & Gross R (1997) Effective community intervention to improve hemoglobin status in preschoolers receiving once-weekly iron supplementation. *Am J Clin Nutr* **65**, 1057-1061.

Pawson R, Greenhalgh T, Harvey G & Walshe K (2005) Realist review--a new method of systematic review designed for complex policy interventions. *J Health Serv Res Policy* **10 Suppl 1**, 21-34.

Paxson C & Schady N (2007) Cognitive development among young children in Ecuador: the roles of wealth, health and parenting. *The Journal of Human Resources* **XLII**, 49-84.

Payne LG, Koski KG, Ortega-Barria E & Scott ME (2007) Benefit of vitamin A supplementation on ascaris reinfection is less evident in stunted children. *J Nutr* **137**, 1455-1459.

Pedro MR, Madriaga JR, Barba CV, Habito RC, Gana AE, Deitchler M & Mason JB (2004) The national Vitamin A Supplementation Program and subclinical vitamin A deficiency among preschool children in the philippines. *Food Nutr Bull* **25**, 319-329.

Penny ME, Creed-Kanashiro HM, Robert RC, Narro MR, Caulfield LE & Black RE (2005) Effectiveness of an educational intervention delivered through the health services to improve nutrition in young children: a cluster-randomised controlled trial. *Lancet* **365**, 1863-1872.

Phiri KS, Calis JC, Faragher B, Nkhoma E, Ng'oma K, Mangochi B, Molyneux ME & van Hensbroek MB (2008) Long term outcome of severe anaemia in Malawian children. *PLoS One* **3**, e2903.

Plahar WA, Nti CA, Quaye W & Larweh PM (2002) Household food availability and food consumption behaviour in the southern sector and middle belt district of Ghana: Food Research Institute (Ghana)/SADAOC.

Powers HJ (2003) Riboflavin (vitamin B-2) and health. *Am J Clin Nutr* **77**, 1352-1360.

Premji Z, Hamisi Y, Shiff C, Minjas J, Lubega P & Makwaya C (1995) Anaemia and Plasmodium falciparum infections among young children in an holoendemic area, Bagamoyo, Tanzania. *Acta Trop* **59**, 55-64.

Prentice AM, Ghattas H & Cox SE (2007a) Host-pathogen interactions: can micronutrients tip the balance? *J Nutr* **137**, 1334-1337.

Prentice AM, Ghattas H, Doherty C & Cox SE (2007b) Iron metabolism and malaria. *Food Nutr Bull* **28**, S524-539.

Pullan R & Brooker S (2008) The health impact of polyparasitism in humans: are we under-estimating the burden of parasitic diseases? *Parasitology* **135**, 783-794.

Ramakrishnan U, Aburto N, McCabe G & Martorell R (2004) Multimicronutrient interventions but not vitamin a or iron interventions alone improve child growth: results of 3 meta-analyses. *J Nutr* **134**, 2592-2602.

Ramakrishnan U & Yip R (2002) Experiences and challenges in industrialized countries: control of iron deficiency in industrialized countries. *J Nutr* **132**, 820S-824S.

Raqib R, Alam DS, Sarker P, Ahmad SM, Ara G, Yunus M, Moore SE & Fuchs G (2007) Low birth weight is associated with altered immune function in rural Bangladeshi children: a birth cohort study. *Am J Clin Nutr* **85**, 845-852.

Rasmussen K (2001) Is There a Causal Relationship between Iron Deficiency or Iron-Deficiency Anemia and Weight at Birth, Length of Gestation and Perinatal Mortality? *J Nutr* **131**, 590S-601S; discussion 601S-603S.

Ratledge C (2007) Iron metabolism and infection. *Food Nutr Bull* **28**, S515-523.

RBM (2010) World Malaria Day 2010: Africa Update. In *Progress & Impact Series No. 2*. Geneva: Roll Back Malaria.

Reed SC, Wirima JJ & Steketee RW (1994) Risk factors for anemia in young children in rural Malawi. *Am J Trop Med Hyg* **51**, 170-174.

Rivera JA, Shamah T, Villalpando S & Monterrubio E (2010) Effectiveness of a large-scale iron-fortified milk distribution program on anemia and iron deficiency in low-income young children in Mexico. *Am J Clin Nutr* **91**, 431-439.

Rivera JA, Sotres-Alvarez D, Habicht JP, Shamah T & Villalpando S (2004) Impact of the Mexican program for education, health, and nutrition (Progresa) on rates of growth and anemia in infants and young children: a randomized effectiveness study. *JAMA* **291**, 2563-2570.

Robert RC, Gittelsohn J, Creed-Kanashiro HM, Penny ME, Caulfield LE, Narro MR & Black RE (2006) Process evaluation determines the pathway of success for a health center-delivered, nutrition education intervention for infants in Trujillo, Peru. *J Nutr* **136**, 634-641.

Robins EB & Blum S (2007) Hematologic reference values for African American children and adolescents. *Am J Hematol* **82**, 611-614.

Roca-Feltrer A, Carneiro I & Armstrong Schellenberg JR (2008) Estimates of the burden of malaria morbidity in Africa in children under the age of 5 years. *Trop Med Int Health* **13**, 771-783.

Rockhill B, Newman B & Weinberg C (1998) Use and misuse of population attributable fractions. *Am J Public Health* **88**, 15-19.

Rohner F, Zimmermann MB, Wegmueller R, Tschannen AB & Hurrell RF (2007) Mild riboflavin deficiency is highly prevalent in school-age children but does not increase risk for anaemia in Cote d'Ivoire. *Br J Nutr* **97**, 970-976.

Ronald LA, Kenny SL, Klinkenberg E, Akoto AO, Boakye I, Barnish G & Donnelly MJ (2006) Malaria and anaemia among children in two communities of Kumasi, Ghana: a cross-sectional survey. *Malar J* **5**, 105.

Ronnenberg AG, Wood RJ, Wang X, Xing H, Chen C, Chen D, Guang W, Huang A, Wang L & Xu X (2004) Preconception hemoglobin and ferritin concentrations are associated with pregnancy outcome in a prospective cohort of Chinese women. *J Nutr* **134**, 2586-2591.

Rosen DS, Haselow NJ & Sloan NL (1993) How to use the HKI food frequency method to assess community risk of vitamin A deficiency. New York, USA: Helen Keller International Vitamin A Technical Assistance Program.

Ruel MT & Levin C (2000) Assessing the Potential for food-based strategies to alleviate vitamin A and iron deficiencies: a review of recent evidence. In *Discussion paper 92*. Washington D.C.: International Food Policy Research Institute.

Ruel MT, Menon P, Habicht JP, Loechl C, Bergeron G, Pelto G, Arimond M, Maluccio J, Michaud L & Hankebo B (2008) Age-based preventive targeting of food assistance and behaviour change and communication for reduction of childhood undernutrition in Haiti: a cluster randomised trial. *Lancet* **371**, 588-595.

Ruel MT, Menon P, Loechl C & Pelto G (2004) Donated fortified cereal blends improve the nutrient density of traditional complementary foods in Haiti, but iron and zinc gaps remain for infants. *Food Nutr Bull* **25**, 361-376.

Santika O, Fahmida U & Ferguson EL (2009) Development of food-based complementary feeding recommendations for 9- to 11-month-old peri-urban Indonesian infants using linear programming. *J Nutr* **139**, 135-141.

Sazawal S, Black RE, Ramsan M, Chwaya HM, Stoltzfus RJ, Dutta A, Dhingra U, Kabole I, Deb S, Othman MK & Kabole FM (2006) Effects of routine

prophylactic supplementation with iron and folic acid on admission to hospital and mortality in preschool children in a high malaria transmission setting: community-based, randomised, placebo-controlled trial. *Lancet* **367**, 133-143.

Schellenberg D, Schellenberg JR, Mushi A, Savigny D, Mgalula L, Mbuya C & Victora CG (2003) The silent burden of anaemia in Tanzanian children: a community-based study. *Bull World Health Organ* **81**, 581-590.

Schellenberg JA, Newell JN, Snow RW, Mung'ala V, Marsh K, Smith PG & Hayes RJ (1998) An analysis of the geographical distribution of severe malaria in children in Kilifi District, Kenya. *Int J Epidemiol* **27**, 323-329.

Schellenberg JR, Abdulla S, Minja H, Nathan R, Mukasa O, Marchant T, Mponda H, Kikumbih N, Lyimo E, Manchester T, Tanner M & Lengeler C (1999) KINET: a social marketing programme of treated nets and net treatment for malaria control in Tanzania, with evaluation of child health and long-term survival. *Trans R Soc Trop Med Hyg* **93**, 225-231.

Scrimshaw NS (2003) Historical concepts of interactions, synergism and antagonism between nutrition and infection. *J Nutr* **133**, 316S-321S.

Scrimshaw NS & SanGiovanni JP (1997) Synergism of nutrition, infection, and immunity: an overview. *Am J Clin Nutr* **66**, 464S-477S.

Semba RD & Bloem MW (2002) The anemia of vitamin A deficiency: epidemiology and pathogenesis. *Eur J Clin Nutr* **56**, 271-281.

Semba RD, de Pee S, Ricks MO, Sari M & Bloem MW (2008) Diarrhea and fever as risk factors for anemia among children under age five living in urban slum areas of Indonesia. *Int J Infect Dis* **12**, 62-70.

Semba RD, Muhilal, West KP, Winget M, Natadisastra G, Scott A & Sommer A (1992) Impact of vitamin A supplementation on hematological indicators of iron metabolism and protein status in children. *Nutr Res* **12**, 469-478.

Serjeant GR (1997) Sickle-cell disease. *Lancet* **350**, 725-730.

Shankar AH, Genton B, Baisor M, Paino J, Tamja S, Adiguma T, Wu L, Rare L, Bannon D, Tielsch JM, West KP, Jr. & Alpers MP (2000) The influence of zinc supplementation on morbidity due to Plasmodium falciparum: a randomized trial in preschool children in Papua New Guinea. *Am J Trop Med Hyg* **62**, 663-669.

Shankar AH, Genton B, Semba RD, Baisor M, Paino J, Tamja S, Adiguma T, Wu L, Rare L, Tielsch JM, Alpers MP & West KP, Jr. (1999) Effect of vitamin A supplementation on morbidity due to Plasmodium falciparum in young children in Papua New Guinea: a randomised trial. *Lancet* **354**, 203-209.

Shet A, Mehta S, Rajagopalan N, Dinakar C, Ramesh E, Samuel NM, Indumathi CK, Fawzi WW & Kurpad AV (2009) Anemia and growth failure among HIV-infected children in India: a retrospective analysis. *BMC Pediatr* **9**, 37.

Shrimpton R, Huffman SL, Zehner ER, Darnton-Hill I & Dalmiya N (2009) Multiple micronutrient supplementation during pregnancy in developing-country settings: policy and program implications of the results of a meta-analysis. *Food Nutr Bull* **30**, S556-573.

Siegel EH, Stoltzfus RJ, Kariger PK, Katz J, Khatry SK, LeClerq SC, Pollitt E & Tielsch JM (2005) Growth indices, anemia, and diet independently predict motor milestone acquisition of infants in south central Nepal. *J Nutr* **135**, 2840-2844.

Siekmann JH, Allen LH, Bwibo NO, Demment MW, Murphy SP & Neumann CG (2003) Kenyan school children have multiple micronutrient deficiencies, but increased plasma vitamin B-12 is the only detectable micronutrient response to meat or milk supplementation. *J Nutr* **133**, 3972S-3980S.

Sirima SB, Konate A, Tiono AB, Convelbo N, Cousens S & Pagnoni F (2003) Early treatment of childhood fevers with pre-packaged antimalarial drugs in the home reduces severe malaria morbidity in Burkina Faso. *Trop Med Int Health* **8**, 133-139.

Slogrove AL, Cotton MF & Esser MM (2010) Severe infections in HIV-exposed uninfected infants: clinical evidence of immunodeficiency. *Journal of Tropical Pediatrics* **56**, 75-81.

Slutsker L & Marston BJ (2007) HIV and malaria: interactions and implications. *Curr Opin Infect Dis* **20**, 3-10.

Smith JC, Makdani D, Hegar A, Rao D & Douglass LW (1999) Vitamin A and zinc supplementation of preschool children. *J Am Coll Nutr* **18**, 213-222.

Smuts CM, Lombard CJ, Benade AJ, Dhansay MA, Berger J, Hop le T, Lopez de Romana G, Untoro J, Karyadi E, Erhardt J & Gross R (2005) Efficacy of a foodlet-based multiple micronutrient supplement for preventing growth faltering, anemia, and micronutrient deficiency of infants: the four country IRIS trial pooled data analysis. *J Nutr* **135**, 631S-638S.

Snow RW, Craig M, Deichmann U & Marsh K (1999) Estimating mortality, morbidity and disability due to malaria among Africa's non-pregnant population. *Bull World Health Organ* **77**, 624-640.

Snow RW, Craig M, Newton CR & Steketee RW (2003) The public health burden of Plasmodium falciparum malaria in Africa: deriving the numbers. In *Working Paper No. 11, Disease Control Priorities Project*. Bethesda, Maryland: Fogarty International Center, National Institutes of Health.

Solomons NW (2002) All that glitters is not iron (deficiency): revisiting the question of why anemic individuals are anemic. *Nutr Rev* **60**, 91-96.

Stein AJ, Meenakshi JV, Qaim M, Nestel P, Sachdev HP & Bhutta ZA (2008) Potential impacts of iron biofortification in India. *Soc Sci Med* **66**, 1797-1808.

Stephenson LS, Holland CV & Cooper ES (2000a) The public health significance of Trichuris trichiura. *Parasitology* **121 Suppl**, S73-95.

Stephenson LS, Latham MC & Ottesen EA (2000b) Malnutrition and parasitic helminth infections. *Parasitology* **121 Suppl**, S23-38.

Stoltzfus RJ (1997) Rethinking anaemia surveillance. *Lancet* **349**, 1764-1766.

Stoltzfus RJ, Albonico M, Chwaya HM, Savioli L, Tielsch J, Schulze K & Yip R (1996) Hemoquant determination of hookworm-related blood loss and its role in iron deficiency in African children. *Am J Trop Med Hyg* **55**, 399-404.

Stoltzfus RJ, Chway HM, Montresor A, Tielsch JM, Jape JK, Albonico M & Savioli L (2004a) Low dose daily iron supplementation improves iron status and appetite but not anemia, whereas quarterly anthelminthic treatment improves growth, appetite and anemia in Zanzibari preschool children. *J Nutr* **134**, 348-356.

Stoltzfus RJ, Chwaya HM, Montresor A, Albonico M, Savioli L & Tielsch JM (2000) Malaria, hookworms and recent fever are related to anemia and iron status

indicators in 0- to 5-y old Zanzibari children and these relationships change with age. *J Nutr* **130**, 1724-1733.

Stoltzfus RJ, Chwaya HM, Tielsch JM, Schulze KJ, Albonico M & Savioli L (1997a) Epidemiology of iron deficiency anemia in Zanzibari schoolchildren: the importance of hookworms. *Am J Clin Nutr* **65**, 153-159.

Stoltzfus RJ & Dreyfuss M (1998) Guidelines for the use of iron supplements to prevent and treat iron deficiency anaemia. Geneva: International Nutritional Anaemia Consultative Group, World Health Organization and UNICEF.

Stoltzfus RJ, Dreyfuss ML, Chwaya HM & Albonico M (1997b) Hookworm control as a strategy to prevent iron deficiency. *Nutr Rev* **55**, 223-232.

Stoltzfus RJ, Heidkamp R, Kenkel D & Habicht JP (2007) Iron supplementation of young children: learning from the new evidence. *Food Nutr Bull* **28**, S572-584.

Stoltzfus RJ, Mullany L & Black RE (2004b) Iron Deficiency Anaemia. In *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors* [M Ezzati, AD Lopez, A Rodgers and CJL Murray, editors]. Geneva: World Health Organization.

Stothard JR & Gabrielli AF (2007) Schistosomiasis in African infants and preschool children: to treat or not to treat? *Trends Parasitol* **23**, 83-86.

Stuart MJ & Nagel RL (2004) Sickle-cell disease. *Lancet* **364**, 1343-1360.

Stuckler D, Basu S & McKee M (2010) Drivers of inequality in millennium development goal progress: a statistical analysis. *PLoS Med* **7**, e1000241.

Subramanian SV, Ackerson LK, Davey Smith G & John NA (2009) Association of maternal height with child mortality, anthropometric failure, and anemia in India. *JAMA* **301**, 1691-1701.

Szymlek-Gay EA, Ferguson EL, Heath AL, Gray AR & Gibson RS (2009) Food-based strategies improve iron status in toddlers: a randomized controlled trial12. *Am J Clin Nutr* **90**, 1541-1551.

Tako E, Laparra JM, Glahn RP, Welch RM, Lei XG, Beebe S & Miller DD (2009) Biofortified black beans in a maize and bean diet provide more bioavailable iron to piglets than standard black beans. *J Nutr* **139**, 305-309.

Takyi EE (1999) Children's consumption of dark green, leafy vegetables with added fat enhances serum retinol. *J Nutr* **129**, 1549-1554.

Tanzania Commission for AIDS, National Bureau of Statistics Tanzania & Macro O (2005) Tanzania HIV/AIDS Indicator Survey 2003-04. Calverton, Maryland, USA: TACAIDS, NBS, and ORC Macro.

Tanzania Commission for AIDS (TACAIDS), Zanzibar AIDS Commission (ZAC), National Bureau of Statistics (NBS), Office of the Chief Government Statistician (OCGS) & Macro International Inc. (2008) Tanzania HIV/AIDS and Malaria Indicator Survey 2007-08. Dar es Salaam, Tanzania: TACAIDS, ZAC, NBS, OCGS, and Macro International Inc.

Tatala S, Ndossi G, Ash D & Mamiro PS (2007) Effect of germination of finger millet on nutritional value of foods and effect of food supplement on nutrition and anaemia status in Tanzanian children. *Tanzania Health Research Bulletin* **9**, 77-86.

Tatala S, Svanberg U & Mduma B (1998) Low dietary iron availability is a major cause of anemia: a nutrition survey in the Lindi District of Tanzania. *Am J Clin Nutr* **68**, 171-178.

Terlouw DJ, Morgah K, Wolkon A, Dare A, Dorkenoo A, Eliades MJ, Vanden Eng J, Sodahlon YK, ter Kuile FO & Hawley WA (2010) Impact of mass distribution of free long-lasting insecticidal nets on childhood malaria morbidity: the Togo National Integrated Child Health Campaign. *Malar J* **9**, 199.

Thomson MC, Connor SJ, Ward N & Molyneux D (2004) Impact of climate variability on infectious disease in West Africa. *EcoHealth* **1**, 138-150.

Thurnham DI, Mburu AS, Mwaniki DL & De Wagt A (2005) Micronutrients in childhood and the influence of subclinical inflammation. *Proc Nutr Soc* **64**, 502-509.

Thurnham DI, McCabe LD, Haldar S, Wieringa FT, Northrop-Clewes CA & McCabe GP (2010) Adjusting plasma ferritin concentrations to remove the effects of subclinical inflammation in the assessment of iron deficiency: a meta-analysis. *Am J Clin Nutr* **92**, 546-555.

Thurnham DI & Northrop-Clewes CA (2007) Infection and the etiology of anemia. In *Nutritional Anemia* [K Kraemer and MB Zimmerman, editors]. Basel: SIGHT AND LIFE Press.

Tielsch JM, Khatry SK, Stoltzfus RJ, Katz J, LeClerq SC, Adhikari R, Mullany LC, Shresta S & Black RE (2006) Effect of routine prophylactic supplementation with iron and folic acid on preschool child mortality in southern Nepal: community-based, cluster-randomised, placebo-controlled trial. *Lancet* **367**, 144-152.

Tolentino K & Friedman JF (2007) An update on anemia in less developed countries. *Am J Trop Med Hyg* **77**, 44-51.

Torrejon CS, Castillo-Duran C, Hertrampf ED & Ruz M (2004) Zinc and iron nutrition in Chilean children fed fortified milk provided by the Complementary National Food Program. *Nutrition* **20**, 177-180.

Totin D, Ndugwa C, Mmiro F, Perry RT, Jackson JB & Semba RD (2002) Iron deficiency anemia is highly prevalent among human immunodeficiency virus-infected and uninfected infants in Uganda. *J Nutr* **132**, 423-429.

Tuntipopipat S, Zeder C, Siriprapa P & Charoenkiatkul S (2009) Inhibitory effects of spices and herbs on iron availability. *Int J Food Sci Nutr* **60 Suppl 1**, 43-55.

UN General Assembly Res S27-2E (11 October 2002) A world fit for children. In *UN Document No. A/RES/S-27/2*.

UNICEF (1990) Strategy for Improved Nutrition of Children and Women in Developing Countries. New York: UNICEF.

UNICEF (1995) Monitoring Progress Toward the Goals of the World Summit for Children: a practical handbook for multiple indicator surveys.

UNICEF (2008) Tracking progress in maternal, newborn & child survival: the 2008 report (2nd edition). New York: United Nations Children's Fund.

UNICEF (2009) The state of the world's children 2009. New York: UNICEF.

United Nations Development Programme (1999) Human Development Report 1999. New York, USA: UNDP.

United Nations Development Programme (2006) Human Development Report 2006. New York, USA: UNDP.

United Republic of Tanzania (1999) Poverty and Welfare Monitoring Indicators [VPs Office, editor. Dar es Salaam.

van Eijk AM, Ayisi JG, Ter Kuile FO, Misore AO, Otieno JA, Kolczak MS, Kager PA, Steketee RW & Nahlen BL (2002) Malaria and human immunodeficiency virus infection as risk factors for anemia in infants in Kisumu, western Kenya. *Am J Trop Med Hyg* **67**, 44-53.

van Hensbroek MB, Morris-Jones S, Meisner S, Jaffar S, Bayo L, Dackour R, Phillips C & Greenwood BM (1995) Iron, but not folic acid, combined with effective antimalarial therapy promotes haematological recovery in African children after acute falciparum malaria. *Trans R Soc Trop Med Hyg* **89**, 672-676.

van Jaarsveld PJ, Faber M, Tanumihardjo SA, Nestel P, Lombard CJ & Benade AJ (2005) Beta-carotene-rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose-response test. *Am J Clin Nutr* **81**, 1080-1087.

Varma JL, Das S, Sankar R, Mannar MG, Levinson FJ & Hamer DH (2007) Community-level micronutrient fortification of a food supplement in India: a controlled trial in preschool children aged 36-66 mo. *Am J Clin Nutr* **85**, 1127-1133.

Veenemans J, Andang'o PE, Mbugi EV, Kraaijenhagen RJ, Mwaniki DL, Mockenhaupt FP, Roewer S, Olomi RM, Shao JF, van der Meer JW, Savelkoul HF & Verhoef H (2008) Alpha+ -thalassemia protects against anemia associated with asymptomatic malaria: evidence from community-based surveys in Tanzania and Kenya. *J Infect Dis* **198**, 401-408.

Verhoef H, West CE, Ndeto P, Burema J, Beguin Y & Kok FJ (2001) Serum transferrin receptor concentration indicates increased erythropoiesis in Kenyan children with asymptomatic malaria. *Am J Clin Nutr* **74**, 767-775.

Verhoef H, West CE, Veenemans J, Beguin Y & Kok FJ (2002) Stunting may determine the severity of malaria-associated anemia in African children. *Pediatrics* **110**, e48.

Victora CG, Wagstaff A, Schellenberg JA, Gwatkin D, Claeson M & Habicht JP (2003) Applying an equity lens to child health and mortality: more of the same is not enough. *Lancet* **362**, 233-241.

Villalpando S, Perez-Exposito AB, Shamah-Levy T & Rivera JA (2006a) Distribution of anemia associated with micronutrient deficiencies other than iron in a probabilistic sample of Mexican children. *Ann Nutr Metab* **50**, 506-511.

Villalpando S, Shamah T, Rivera JA, Lara Y & Monterrubio E (2006b) Fortifying milk with ferrous gluconate and zinc oxide in a public nutrition program reduced the prevalence of anemia in toddlers. *J Nutr* **136**, 2633-2637.

Villamor E & Fawzi WW (2005) Effects of vitamin a supplementation on immune responses and correlation with clinical outcomes. *Clin Microbiol Rev* **18**, 446-464.

Villamor E, Mbise R, Spiegelman D, Ndossi G & Fawzi WW (2000) Vitamin A supplementation and other predictors of anemia among children from Dar Es Salaam, Tanzania. *Am J Trop Med Hyg* **62**, 590-597.

Vuong le T, Dueker SR & Murphy SP (2002) Plasma beta-carotene and retinol concentrations of children increase after a 30-d supplementation with the fruit Momordica cochinchinensis (gac). *Am J Clin Nutr* **75**, 872-879.

Vyas S & Kumaranayake L (2006) Constructing socio-economic status indices: how to use principal components analysis. *Health Policy Plan* **21**, 459-468.

Wachs TD, Creed-Kanashiro H, Cueto S & Jacoby E (2005) Maternal education and intelligence predict offspring diet and nutritional status. *J Nutr* **135**, 2179-2186.

Wagstaff A & Watanabe N (2003) What difference does the choice of SES make in health inequality measurement? *Health Econ* **12**, 885-890.

Wamani H, Astrom AN, Peterson S, Tumwine JK & Tylleskar T (2007) Boys are more stunted than girls in sub-Saharan Africa: a meta-analysis of 16 demographic and health surveys. *BMC Pediatr* **7**, 17.

Wander K, Shell-Duncan B & McDade TW (2009) Evaluation of iron deficiency as a nutritional adaptation to infectious disease: an evolutionary medicine perspective. *Am J Hum Biol* **21**, 172-179.

Weatherall DJ (1997) The thalassaemias. *BMJ* **314**, 1675-1678.

Weiss G & Goodnough LT (2005) Anemia of chronic disease. *N Engl J Med* **352**, 1011-1023.

West KP, Jr., Gernand AD & Sommer A (2007) Vitamin A in nutritional anemia. In *Nutritional Anemia* [K Kraemer and MB Zimmerman, editors]. Basel: Sight and Life Press.

WHO (2002) Reducing risks, promoting healthy life. The world health report 2002. Geneva: World Health Organization.

WHO (2005a) Guiding principles for feeding non-breastfed children 6-24 months of age. Geneva: World Health Organization.

WHO (2005b) The Roll Back Malaria strategy for improving access to treatment through home management for malaria. Geneva: World Health Organization.

WHO (2006a) Preventive chemotherapy in human helminthiasis: coordinated use of anthelminthic drugs in control interventions: a manual for health professionals and programme managers. Geneva: World Health Organization.

WHO (2006b) WHO statement: Iron supplementation of young children in regions where malaria transmission is intense and infectious disease highly prevalent. Geneva: World Health Organization.

WHO (2007a) Commission on Social Determinants of Health. Priority Public Health Conditions Knowledge Network. Scoping paper: priority public health conditions. Geneva. Retrieved March 13, 2011, from http://www.who.int/social_determinants/resources/pphc_scoping_paper.pdf.

WHO (2007b) WHO Anthro for personal computers: software for assessing growth and development of the world's children. Geneva: World Health Organization.

WHO (2008) Impact of long-lasting insecticidal-treated nets (LLINs) and artemisinin-based combination therapies (ACTs) measured using surveillance data, in four African countries. Geneva: World Health Organization.

WHO (2010) Guidelines for the treatment of malaria, 2nd ed. Geneva: World Health Organization.

WHO Multicentre Growth Reference Study Group (2006) WHO Child Growth Standards based on length/height, weight and age. *Acta Paediatrica* **Suppl 450**, 76-85.

WHO/CDC (2005) Assessing the iron status of populations : report of a Joint World Health Organization/Centers for Disease Control and Prevention Technical Consultation on the Assessment of Iron Status at the Population Level, Geneva, Switzerland, 6–8 April 2004. Geneva: World Health Organization.

WHO/FAO (2004) *Vitamin and minerval requirements in human nutrition*, 2nd ed ed. Geneva: WHO/FAO.

WHO/UNICEF (2004) Focusing on anaemia: towards an integrated approach for effective anaemia control. Geneva: World Health Organization.

WHO/UNICEF (2005) Model IMCI handbook: Integrated management of childhood illness. Geneva: World Health Organization.

WHO/UNICEF/IFPRI/UC Davis/USAID/FANTA (2008) Indicators for assessing infant and young child feeding practices. Geneva: World Health Organization.

WHO/UNICEF/IVACG (1997) Vitamin A supplements: a guide to their use in the treatment and prevention of vitamin A deficiency and xerophthalmia (2nd edition). Geneva: World Health Organization.

WHO/UNICEF/UNU (2001) Iron Deficiency Anaemia Assessment, Prevention and Control: a guide for programme managers. Geneva: World Health Organization.

Williams TN, Mwangi TW, Wambua S, Alexander ND, Kortok M, Snow RW & Marsh K (2005) Sickle cell trait and the risk of Plasmodium falciparum malaria and other childhood diseases. *J Infect Dis* **192**, 178-186.

World Vision Canada (1996) MICAH Guide. Mississauga: World Vision Canada.

World Vision Canada (2006a) World Vision Ghana MICAH Program: Final Evaluation Report. Mississauga, Canada: World Vision Canada.

World Vision Canada (2006b) World Vision Malawi MICAH Program: Final Evaluation Report. Mississauga, Canada: World Vision Canada.

World Vision Canada (2006c) World Vision Tanzania MICAH Program: Final Evaluation Report. Mississauga, Canada: World Vision Canada.

Yeboah-Antwi K, Pilingana P, Macleod WB, Semrau K, Siazeele K, Kalesha P, Hamainza B, Seidenberg P, Mazimba A, Sabin L, Kamholz K, Thea DM & Hamer DH (2010) Community case management of fever due to malaria and pneumonia in children under five in Zambia: a cluster randomized controlled trial. *PLoS Med* **7**, e1000340.

Yeudall F, Gibson RS, Cullinan TR & Mtimuni B (2005) Efficacy of a community-based dietary intervention to enhance micronutrient adequacy of high-phytate maize-based diets of rural Malawian children. *Public Health Nutr* **8**, 826-836.

Yeudall F, Gibson RS, Kayira C & Umar E (2002) Efficacy of a multi-micronutrient dietary intervention based on haemoglobin, hair zinc concentrations, and selected functional outcomes in rural Malawian children. *Eur J Clin Nutr* **56**, 1176-1185.

Yip R & Dallman PR (1996) Iron. In *Present Knowledge in Nutrition* [EE Ziegler and LJ Filer, Jr., editors]. Washington DC: ILSI Press.

Zakai NA, McClure LA, Prineas R, Howard G, McClellan W, Holmes CE, Newsome BB, Warnock DG, Audhya P & Cushman M (2009) Correlates of anemia in

American blacks and whites: the REGARDS Renal Ancillary Study. *Am J Epidemiol* **169**, 355-364.

Zeba AN, Sorgho H, Rouamba N, Zongo I, Rouamba J, Guiguemde RT, Hamer DH, Mokhtar N & Ouedraogo JB (2008) Major reduction of malaria morbidity with combined vitamin A and zinc supplementation in young children in Burkina Faso: a randomized double blind trial. *Nutr J* **7**, 7.

Zhang J & Yu KF (1998) What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. *JAMA* **280**, 1690-1691.

Zimmerman MB (2007) Interactions between iron and vitamin A, riboflavin, copper, and zinc in the etiology of anemia. In *Nutritional Anemia* [K Kraemer and MB Zimmerman, editors]. Basel: SIGHT AND LIFE Press.

Zimmermann MB, Biebinger R, Rohner F, Dib A, Zeder C, Hurrell RF & Chaouki N (2006) Vitamin A supplementation in children with poor vitamin A and iron status increases erythropoietin and hemoglobin concentrations without changing total body iron. *Am J Clin Nutr* **84**, 580-586.

Zimmermann MB, Zeder C, Muthayya S, Winichagoon P, Chaouki N, Aeberli I & Hurrell RF (2008) Adiposity in women and children from transition countries predicts decreased iron absorption, iron deficiency and a reduced response to iron fortification. *International Journal of Obesity* **32**, 1098-1104.

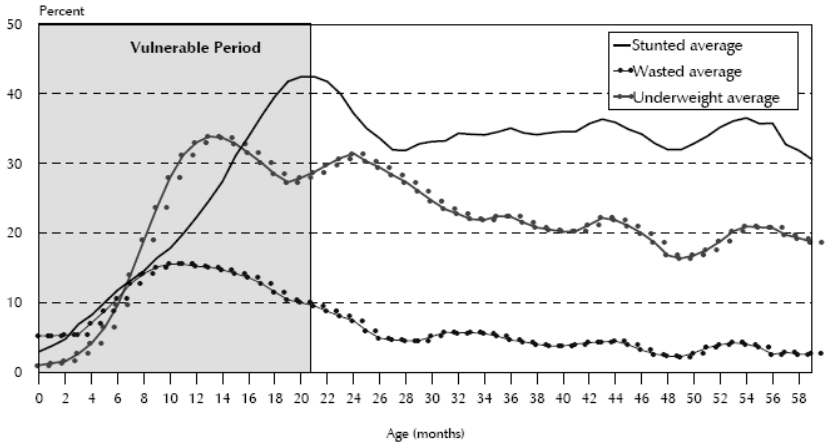
Zlotkin SH, Christofides AL, Hyder SM, Schauer CS, Tondeur MC & Sharieff W (2004) Controlling iron deficiency anemia through the use of home-fortified complementary foods. *Indian J Pediatr* **71**, 1015-1019.

Zlotkin SH, Schauer C, Christofides A, Sharieff W, Tondeur MC & Hyder SM (2005) Micronutrient sprinkles to control childhood anaemia. *PLoS Med* **2**, e1.

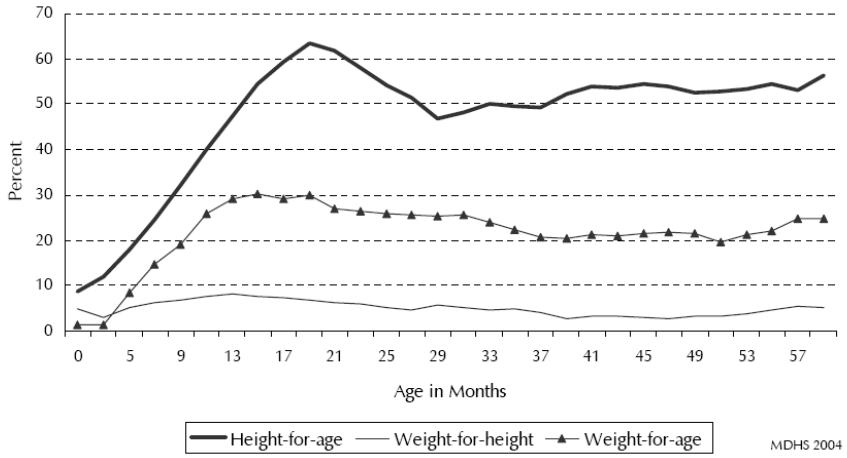
# Appendices

# A. Comparison of child growth by country

**A**




**B**




**C**

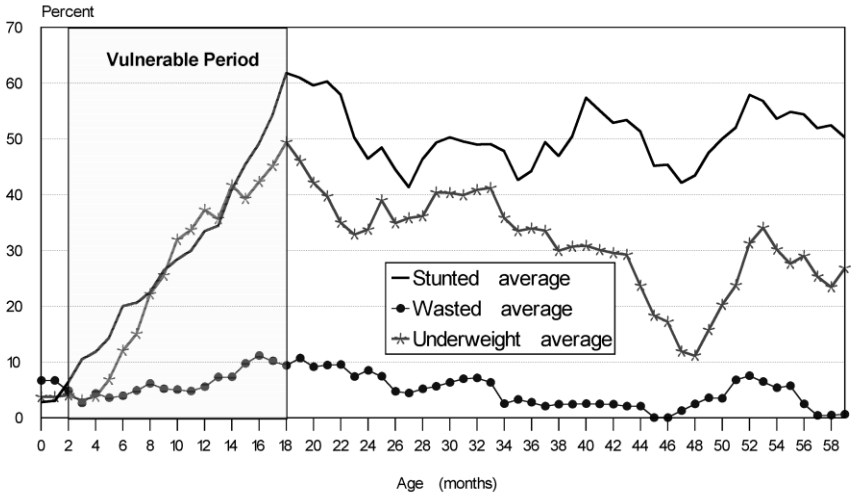



Figure A.1: Stunting, wasting and underweight by age in children 0-59 mo

A) Ghana (GSS et al., 2004); B) Malawi (MDHS 2004); C) Tanzania (ORC Macro, 2001)

# B. MICAH Program Theory (Logical Framework)

**GOAL: To improve the health and well-being of women and children**

| OUTCOME | OUTPUT | ACTIVITIES |
|---|---|---|
| **1.0 Reduced prevalence of vitamin A, iron and iodine deficiency in women and children.** | **1.1 Increased intake of micronutrients through supplementation** | **1.1.1 Vitamin A Supplementation (VAS)**<br>• VAS to children 6-59 mo & 6-14 y<br>• VAS to lactating mothers through CHWs<br>• Develop and use IEC materials and methods<br>**1.1.2 Iron Supplementation (IS)**<br>• IS to children 6-59 mo, school age children, WRA<br>• IS to pregnant women through ANC and CHWs<br>• Develop and use IEC materials and methods |
| | **1.2 Increased intake of micronutrients through fortification** | **1.2.1 Iodized salt promotion**<br>**1.2.2 Promotion of fortified complementary foods**<br>• Produce fortified complementary foods<br>• Social marketing of locally fortified foods<br>**1.2.3 Community level fortification of staple foods**<br>• Provide equipment<br>• Train millers and health workers<br>• Orientation for local leaders, village health committees<br>• Help to establish independent fortification business<br>• Quality control system |
| | **1.3 Increased intake of micronutrient-rich foods through dietary diversification/ modification** | **1.3.1 Promotion of DDM**<br>• Kitchen/community gardens, fruit tree propagation<br>• Soya and ground nut production<br>• Raising of poultry and small livestock<br>• Fish farming<br>• Local seed multiplication<br>• IEC (e.g. food demonstrations) |
| | **1.4 Increased intake of micronutrients through appropriate child feeding practices** | **1.4.1 Promotion of appropriate child feeding practices**<br>• Baby friendly hospital initiative<br>• Mothers, grandmothers and CHW training<br>• IEC materials and methods |

| OUTCOME | OUTPUT | ACTIVITIES |
|---|---|---|
| **2.0 Reduce prevalence of diseases that affect micronutrient status (malaria, diarrheal, other parasitic & vaccine-preventable diseases)** | **2.1 Improved access to clean drinking water and improved sanitary conditions** | **2.1.1 Improve access to clean water**<br>• Provide potable water sources, where necessary<br>• Protect existing water sources<br>• IEC on maintaining clean water sources<br>**2.1.2 Improve sanitary conditions**<br>• Promote pit latrine construction and use<br>• IEC re. environmental sanitation<br>• Promote household level sanitation practices (refuse disposal, soakaways)<br>• Form/strengthen water and sanitation committees |
| | **2.2 Improved control of malaria, other parasites, vaccine-preventable diseases and HIV/AIDS** | **2.2.1 Malaria control**<br>• Promote community based malaria control<br>• Promote use of insecticide treated bednets<br>• IEC re: prevention and treatment of malaria<br>**2.2.2 Control of intestinal, parasitic, vaccine preventable diseases and HIV/AIDS**<br>• Deworming of children <5 y and school age<br>• Treatment of schisto in school age children<br>• Develop and use IEC materials and methods re: prevention of parasitic diseases<br>• Develop and use IEC materials and methods re: HIV/AIDS prevention and nutritional care of PLWHA<br>• Immunization of children <2 y<br>• Growth monitoring of children <3 y |
| **3.0 Enhanced partner capacity to deliver MN & health programming** | **3.1 Enhanced capacity to manage and deliver programs, including monitoring and evaluation** | **3.1.1 Provision of training**<br>• Staff/MOH/CHWs re: management principles, gender analysis, environmental assessment<br>• Field workers re: IEC material and methods<br>• CHWs re: relevant skills and knowledge (eg., weighing and measuring children, causes and prevention of intestinal parasites)<br>• Upgrade staff MN knowledge through attending seminars, conferences<br>• IEC materials and methods developed to be gender |

| OUTCOME | OUTPUT | ACTIVITIES |
|---|---|---|
| | | sensitive<br>**3.1.2 Provision of equipment/ materials**<br>• Equipment to support immunization campaigns; growth monitoring; health hut construction; laboratory services<br>• Supply of medications to CHWs and health posts<br>**3.1.3 Implement effective monitoring and evaluation**<br>• Training of staff at all levels in program monitoring and evaluation<br>• Regular supervision<br>• Training sessions on MND screening techniques<br>• Conduct baseline, midterm and end of project surveys<br>• Facilitate data analysis/interpretation workshop |
| | **3.2 Enhanced ability to advocate for policy changes** | **3.2.1 Enhance advocacy**<br>• Utilize existing mass media<br>• Organize MICAH days<br>• Support government efforts in formulating food and nutrition policy<br>• Network with other nutrition programs<br>• Train partners to advocate for improved MN and health policy at district and community levels |

# C. Summary of program monitoring data

Table C.1: Intervention coverage achieved based on total target population, Ghana

| Activity description | No. eligible | Coverage[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1998 | 1999 | 2000 | 2001 | 2002[2] | 2003 | 2004 | 2005 |
| **Increased intake of micronutrients through supplementation** | | | | | | | | | |
| Multivitamin+iron syrup to children 6-59 mo | 27,000 | 16% | 30% | 34% | 30% | 64% | 29% | 39% | 45% |
| Iron/folate tablets to non-pregnant women 15-49 y | 25,500 | 17% | 36% | 42% | 35% | 42% | 23% | 39% | 39% |
| Education sessions on anaemia/iron supplements | | | | | | | | | |
| • By CHW in communities for women and men | 75,000 | N/A | N/A | 6% | 10% | 1% | 2% | 2% | 3% |
| • By SDHT for women | 33,000 | N/A | N/A | N/A | N/A | 36% | 14% | 11% | 13% |
| Vitamin A capsules to children 6-59 mo, per 6 mo | 40,269 | 11% | 94% | 125% | 100% | 117% | 106% | 112% | 113% |
| **Increased intake of micronutrients through dietary diversification** | | | | | | | | | |
| Farmer training by MOFA staff, no. per year | N/A | N/A | N/A | N/A | 793 | 583 | 1,674 | 0 | 1,546 |
| Households with backyard gardens | 25,000 | N/A | N/A | 4% | 4% | 3% | n/a | n/a | n/a |
| Small animals distributed (chickens, goats, rabbits) to households, no. per year | N/A | — | — | — | — | — | 115 goats 450 rabbit | 2,120 chickens | 0 |
| Citrus fruit seedlings distributed, no. per year | N/A | 0 | N/A | N/A | 350 | 541 | 400 | 1050 | 0 |
| Food demonstrations, no. per year (attendance/y) | N/A | — | — | (4,638) | (2,316) | 0 | 45 (11,080) | 34 (1,951) | 89 (15,754) |
| **Appropriate child feeding practices** | | | | | | | | | |
| SDHT breastfeeding education session attendance | 75,000 | 3% | N/A | 2% | 2% | 2% | 6% | 4% | 6% |
| CHW child feeding education session attendance | 75,000 | n/a | 13%[3] | <1% | <1% | <1% | 1% | 2% | 2% |
| **Improved access to clean drinking water and improved sanitary conditions** | | | | | | | | | |
| VIP latrines constructed, no. per year | N/A | 0 | 30 | 45 | n/a | 0 | | 572 | |
| New or protected water sources, no. per year | N/A | 8 | 1 | 13 | 13 | 0 | | 10 | |
| **Improved control of malaria, intestinal and other parasites, vaccine-preventable diseases and HIV/AIDS** | | | | | | | | | |
| ITNs distributed by SDHT, no. per year | N/A | — | — | — | — | — | 0 | 2,000 | 668 |
| Participants at malaria education sessions by CHW | 75,000 | — | — | 5% | 6% | 2% | 2% | 2% | 2.5% |
| Hookworm treatment for children 6-59 mo[4] | 27,000 | 10% | 27% | 37% | 17% | 42% | 33% | 22% | 11% |
| **Enhanced administrative and management partner capacity to implement MN programs, including monitoring & evaluation** | | | | | | | | | |
| District and sub-district staff trained | N/A | 64 | 111+17 | 49 | 10 | 0 | | 98 | |
| Community health workers trained per year | 1100 (10 per community) | 426 | 605 | 592 +91 TBA | 0 | 0 | | 1,080 | |

*Continued on next page*

Table C.1: Intervention coverage achieved based on total target population, Ghana, *continued*

[1] Unless otherwise specified, coverage is calculated as the average achieved per quarter in any given year.
[2] Missing data for three quarters.
[3] Refers to number of community members receiving education on nutrition and health in general.
[4] Calculated as average of two 6-mo periods, since activity was monitored quarterly but represented coverage from different subdistricts every 6 mo.

Table C.2: Intervention coverage achieved based on total target population, Malawi[1]

| Indicator | Eligible population | Phase 1 1998 | 1999 (1 quarter) | 2000 | 2001 | 2002 (6 mo only) | Phase 2 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|
| **Increased intake of micronutrients through supplementation** | | | | | | | | | |
| Children U5 received iron supplements | Ph1: 311,580<br>Ph2: 210,000 | N/A | 29,929<br>10% | 27,673<br>9% | 66,899<br>21% | 64,138<br>21% | 16,105<br>8% | 28,340<br>13% | 35,123<br>17% |
| Anaemic children treated, n per year | | N/A | 3,518 | 11,261 | 1,644 | N/A | 1,085 | 1,290 | 1,340 |
| Community education sessions on anaemia/iron, n (attendance) | | N/A | N/A | N/A | N/A | N/A | 148<br>(10,371) | 273<br>(16,853) | 237<br>(16,986) |
| **Increased intake of micronutrients through fortification** | | | | | | | | | |
| Households fortifying flour | 20,000 | N/A | 640 | 179 | 6,922 | 6,663 | 3,932 | 5,514 | 6,211 |
| **Increased intake of micronutrients through dietary diversification** | | | | | | | | | |
| People educated on micronutrients | | N/A | 26,611 | 45,284 | 15,599 | N/A | 13,217 | 30,871 | 35,217 |
| Households with gardens of indigenous DGLV | Ph1: 305,471<br>Ph2: 250,000 | N/A | 3,066 | 5,421 | 8,157 | 4,535 | 2,586 | 7,910 | 28,942 |
| Households receiving/raising targeted animals, n per year | Ph1: 305,471<br>Ph2: 250,000 | N/A | 812 | 4,509 | 1,300<br>(6 mo only) | N/A | 3,613 | 7,011 | 4,746 |
| **Appropriate feeding practices** | | | | | | | | | |
| Breastfeeding education sessions (attendance) | | N/A | N/A | N/A | 49<br>(4203) 1Q | N/A | 61<br>(3,980) | 95<br>(7,033) | 72<br>(6,836) |
| **Improved access to clean drinking water and improved sanitary conditions** | | | | | | | | | |
| Water sources constructed, repaired or protected, n per year | | N/A | 32 | 146 | 104<br>(6 mo only) | N/A | 82 | 156 | 278 |
| Pit latrines constructed, n per year | | N/A | 2,040 | 7,587 | 4,353 | N/A | 2,577 | 4,124 | 5,813 |
| **Improved control of malaria, intestinal and other parasites, vaccine-preventable diseases and HIV/AIDS** | | | | | | | | | |
| DRF established, n per year | 2,500 | N/A | 32 | 33 | 0 | N/A | 54 | 89 | 34 |
| ITN distributed, n per year | | — | — | — | — | — | 17,119 | 47,341 | 32,466 |
| Children U5 treated for malaria, n per year | 210,000 | N/A | N/A | N/A | N/A | N/A | 9,176 | 12,102 | 10,537 |
| Children dewormed at school and U5 clinics (ph1) | ? | N/A | 173,020 | 51,758 | 51,444 | 61,090 | N/A | N/A | N/A |
| Children 2-5 y dewormed | Ph2: 105,000 | N/A | N/A | N/A | N/A | N/A | 5,845 | 12,384 | 11,624 |
| **Enhanced administrative and management partner capacity to implement MN programs, including monitoring & evaluation** | | | | | | | | | |
| Village health volunteers trained (IS) | | N/A | 370 | 219 | 0 | N/A | 668 | 336 | 501 |

[1] Unless otherwise specified, percent coverage is based on average number per quarter (or 6-mo period) divided by total eligible population.

Table C.3: Intervention coverage achieved based on total target population, Tanzania

| Indicator[1] | Apr-Sep 1998 | Oct'98 to Sep'99 | Oct'99 to Sep'00*[1] | Oct'00 to Sep'01 | Oct'01 to Sep'02 | Nov'02 to Sep'03 | Oct'03 to Sep'04 | Oct'04 to Sep'05 |
|---|---|---|---|---|---|---|---|---|
| **Increased intake of micronutrients through supplementation** | | | | | | | | |
| Iron supplements to children 24-59 mo | — | — | — | — | — | 27% | 47% | 40% |
| Anaemic children treated, n (% of anaemic children[2]) | 2,124 (6%) | 458 (1%) | 1,048*[2] (3%) | 1,621*[1] (5%) | n/a | 7,840 (20%) | 20,388 (52%) | 28,382 (72%) |
| Education sessions on anaemia/iron, n | 0 | 0 | 112 | 52 | 0 | 930 | 1,193 | 1,259 |
| Vitamin A supplements to children U5[3] | 67% | 56% | 40% | 74% | 94% | 88% | 100% | 85% |
| **Increased intake of micronutrients through fortification** | | | | | | | | |
| Households fortifying flour | — | — | — | — | 23% | 24% | 31% | 37% |
| **Increased intake of micronutrients through dietary diversification** | | | | | | | | |
| People educated on gardening | 0 | 60 groups | 119 groups | n/a | n/a | 334/qtr | 412/qtr | 320/qtr |
| Households with gardens or fruit trees | — | — | — | 0.7% | 3% | 2% | 3% | 3% |
| Households raising chickens | — | — | 5 groups | n/a | 6% | 3% | 4% | 4% |
| **Appropriate feeding practices** | | | | | | | | |
| Women's groups promoting EBF | — | — | — | — | — | 20/20 | 20/20 | 27/20 |
| Pregnant women trained | — | 234 | n/a | n/a | n/a | 28% | 37% | 35% |
| **Improved access to clean drinking water and improved sanitary conditions** | | | | | | | | |
| Homes visited by VHW | 0 | 22% | n/a | 55% | n/a | 25% | 33% | 30% |
| Pit latrines constructed, n | — | — | — | 399 | 386 | 6,284 | 9,633 | 11,331 |
| Households with new water source, n | n/a | 500 | n/a | 500 | 1,000 | n/a | n/a | n/a |
| **Improved control of malaria, intestinal and other parasites, vaccine-preventable diseases and HIV/AIDS** | | | | | | | | |
| ITN distributed to households, n | | | | 1,000 | 2,100 | 6,295 | 3,530 | 6,572 |
| Malaria cases treated (U5 & WRA), n | 1,533 | 1,858 | 2,341 | 5,963[4] | n/a | 2,984 | 2,460 | 2,659 |
| Children U5, n | 1,133 | 785 | 1,401 | n/a | n/a | n/a | n/a | n/a |
| Deworming treatment for children U5 and school children | — | 7,200 SC | 2,712 U5<br>11,843 SC | 11,259 U5<br>6,500 SC | 0 | 85% | 50% | 75% |
| Immunization (†measles), % of district target | 73% | 82% | 78% | 75%*[3] | 74% | 81%† | 92%† | 90%† |
| **Enhanced administrative and management partner capacity to implement MN programs, including monitoring & evaluation** | | | | | | | | |
| Community health worker training | 27 VHW<br>14 TBA | 36 VHW<br>90 TBA | 20 VHW<br>42 TBA | 10VHW<br>40 TBA, 46 TH | 25 CHW<br>45 HW | 100 CHW<br>50 HW | 100 CHW<br>50 HW | 100 CHW<br>50 HW |
| Training/refresher sessions held | — | — | — | — | — | 160 | 180 | 376 |
| Health workers supervising program activities | n/a | n/a | n/a | n/a | n/a | 25 | 25 | 25 |

*Continued on next page*

Table C.3: Intervention coverage achieved based on total target population, Tanzania, *continued*

*Missing data – 1=one quarter; 2=two quarters; 3=three quarters; — activity not done; N/A: activity was being done but information on coverage not available

[1] Unless otherwise specified, coverage given is based on proportion of eligible recipients in that time period.

[2] Used 1997 and 2000 survey anaemia prevalence for children U5 to estimate number of anaemic children. Phase 1: 88% anaemia x 39,600 = 34,848; Phase 2: 77% anaemia x 51,000 = 39,270.

[3] The annual results of this indicator were difficult to monitor due to the differences in reporting by the MOH; data often included many children from outside the MICAH intervention area.

[4] Includes treatment provided to survey respondents who were identified as having malaria parasitemia.

# D. MICAH Standard Questionnaire[26]

## IDENTIFICATION SECTION

**INTERVIEWER:** *Begin by introducing yourself - for example, 'We are from_____ and would like some information that will help us improve the health of mothers and children. The questions will take a short time and we would like to speak with the women of the household. We would also like to measure you children's size, and measure your blood strength. The measurements of your blood strength and child's weight and length will help to find mothers and children who are healthy and those who are not. The information will not be given to other people.'*

**NGO no**. _____ **Cluster no**. _____ **Household no**. _____

| | | |
|---|---|---|
| Region: | Zone: | District: |
| Project Area: | Village: | Call-back necessary?<br>Yes/No<br>Time: |
| Interviewer: | Date of interview<br>(day/mo/yr) | Name of Interviewee: |
| Data entry clerk no.: | All forms completed?<br>1 yes<br>2 refusal 3 not at home<br>9 other _____ | |

Supervisor _____ Checked (signature) _____ Date _____

[26] Source: The MICAH Guide, Section 2.6 (World Vision Canada)

## HOUSEHOLD CHARACTERISTICS (Section A)

**NGO no**. _____ **Cluster no**. _____ **Household no**. _____

**Interviewer**: *Fill in the following information about each person in the household, listing the first person's name in column 01 and so on.* **Can you tell me the names and ages of all members of the household who stayed in the household last night?**

**Household Member Listing Form**

| House hold member No. | First name of household member | Relation to house hold head **(A)** | Sex M=1 F=2 | Age (yr) | Marital Status **(B)** | Work Status **(C)** | Highest level of Education **(D)** | Read/ Write **(E)** |
|---|---|---|---|---|---|---|---|---|
| 01 | | | | | | | | |
| 02 | | | | | | | | |
| 03 | | | | | | | | |
| 04 | | | | | | | | |
| 05 | | | | | | | | |
| 06 | | | | | | | | |
| 07 | | | | | | | | |
| 08 | | | | | | | | |
| 09 | | | | | | | | |
| 10 | | | | | | | | |
| 11 | | | | | | | | |
| 12 | | | | | | | | |
| 13 | | | | | | | | |
| 14 | | | | | | | | |

**(A)**
**1** head
**2** spouse
**3** child
**4** other relative
**5** no relation

**(B)**
**1** single
**2** married mono
**3** married poly
**4** divorced/ separated
**5** widowed

**(C)**
**1** farmer
**2** pastoralist
**3** regular wage earner
**4** casual employee
**5** business/trade
**6** fisherman
**7** domestic/house work
**8** student/pupil
**9**other _____

**(D)**
**0** none
**1** Koran/church
**2** elementary 1-6
**3** junior 7-8
**4** high school 7-12
**5** university/ college
**9** other _____

**(E)**
**1** Read
**2** Write
**3** Both
**4** Neither

**HOUSEHOLD CHARACTERISTICS (Section B)**

**NGO no. _____ Cluster no. _____ Household no. _____**

1. What is your tribe or ethnicity? _____ (country specific)

2. What is the religion of your household? _____
   **1** orthodox **4** protestant
   **2** catholic **5** no church
   **3** muslim **9** other _____

3. What kind of fuel do you use? _____
   **1** wood collected ⇨ **GO TO QUESTION 4**
   **2** wood purchased ⇨ **GO TO QUESTION 4**
   **3** cow dung ⇨ **GO TO QUESTION 4**
   **4** kerosene ⇨ **GO TO QUESTION 7**
   **9** other _____ ⇨ **GO TO QUESTION 7**

4. How long do you travel to get to the place where you collect fuel? ___ (to the nearest ½ hour)

5. How often do you collect fuel? _____
   **1** daily **3** fortnightly
   **2** weekly **9** other _____

6. Who collected the fuel that you are now using? ____
   **1** wife **4** son
   **2** husband **9** other _____
   **3** daughter

7. Material of roof of dwelling: _____
   **1** reeds/grass **4** wood
   **2** tin/metal **9** other _____
   **3** tile

8. No of rooms in dwelling: _____

9. Do you have any of the following items (**1** Yes **0** No)?

| | | | |
|---|---|---|---|
| Radio | ____ | Bed with mattress | _____ |
| TV | ____ | Paraffin lamp with glass | _____ |
| Taperecorder | ____ | Chair | _____ |
| Bicycle | ____ | Table | _____ |

## AGRICULTURE AND FOOD MODULE

**NGO no. _____ Cluster no. _____ Household no. _____**

1. What is the holding size of your land? ___ (to the nearest 0.25 hectare)
   **999** Don't know

2. Who owns the land? ___
   **1** self
   **2** government
   **3** landowner/estate
   **4** village chief
   **9** other (describe) _____

3. Do you have a vegetable and/or fruit garden? _____
   **1** Yes
   **0** No ⇨ **If no, GO TO QUESTION 5**

4. If yes, what do you do with the (a) fruits? _____
   (b) vegetables? _____

   **1** mainly consume
   **2** mainly sell
   **3** consume and sell equally
   **9** other (specify)_____

5. What animals do you have? (More than one answer can be noted.)
   **1** cattle ___
   **2** chickens ___
   **3** goats ___
   **4** sheep ___
   **9** other (specify) _____

6. If you have cattle (or any of the above-noted animals), how do you use the products?
   (*Fill in the table below with uses as they correspond to each animal*)

   **1** mainly consume
   **2** mainly sell
   **3** about equally consume and sell
   **9** other use of products(specify)_____

| | **Meat** | **Milk** | **Cheese** | **Butter** | **Eggs** |
|---|---|---|---|---|---|
| **Cattle** | | | | | |
| **Chickens** | | | | | |
| **Goats** | | | | | |
| **Sheep** | | | | | |
| **Other** | | | | | |

## WATER AND SANITATION MODULE

**NGO no. _____ Cluster no. ___ Household no.____**

**INTERVIEWER:** *Ask the questions in this module once for each household visited. Record the number for only one answer in the space at right. If a respondent gives more than one answer, enter the most usual source/facility:*

1. What is the main source of drinking water for members of your household?

During the wet season? ____ If other (**99**), specify_____
During the dry season? ____ If other (**99**), specify_____

**1** river
**2** lake/dam
**3** pond
**4** unprotected dug well
**5** unprotected spring
**6** roof catchment
**7** protected dug well
**8** protected spring
**9** piped water
**10** tube well/borehole
**99** other (describe) _____

**If answer to either (wet or dry season) is any of 7-10, ⇨ GO TO QUESTION 2**
**Otherwise, GO TO QUESTION 3**

2. Who maintains the water source? _____

**1** government
**2** local authority
**3** NGO/church
**4** community leaders
**5** village committee
**6** natural
**7** owner/self
**9** other _____

3. How long does it take to get there, get water and come back?

Wet season? _____
Dry season? _____

**1** on premises
**2** 0-30 minutes
**3** 30 minutes to 1 hour
**4** 1 to 2 hours
**5** 2 to 3 hours
**6** more than 3 hours
**7** don't know

**WATER AND SANITATION MODULE** (cont')

**NGO no. _____ Cluster no. ___ Household no.____**

4. Who usually fetches the water? ____

**1** wife
**2** husband
**3** son
**4** daughter
**9** other

5. How did you fetch this water? ____

**1** human
**2** cart/wheel barrow
**3** animals
**4** bicycle
**9** other (describe) _____

6. How do you dispose of excreta? _____

**1** bush/open field
**2** communal pit latrine
**3** VIP
**4** private toilet/latrine
**5** flush toilet
**9** other_____

## MORTALITY MODULE

**INTERVIEWER**: *For this module, women should be the interviewers whenever possible. Fill in the following information for each woman in the household between 15 and 49 years of age who has ever had a child.*

- ***Fill out a separate Birth Listing Form for each woman.***
- *Copy each woman's household number and name from the Household Member Listing Form (Household Characteristics - Section A).*
- *Then, go to each mother and ask her the following questions, recording the answers on the corresponding table.*
- *Each mother should be interviewed* ***alone*** *in order to avoid "group" answers to questions.*

**I would like to ask you some questions about any children you have had who were born alive, even if they have died. What is the name of your last child born alive?** *(Copy the child's number from the Household Member Listing Form if the child is still living at home).*

**Was [name of child] born a boy or girl?** *Ask if the child has a birth certificate and copy down the date of birth, noting the source. Ask the mother directly, if no birth certificate is available, for the month and year that the child was born.*

**When was the child born? Is the child still alive?** *If the child is not alive, ask the mother about the child's age at death (in months). Continue to ask for the* ***next last live birth and the live birth previous to that****. The form should be completed for the* ***three*** *most recent live births of the mother. There is one space provided for a twin.*

*Make sure that the mother understands that these questions all refer to her own biological children who were live-born.*

- *Only include babies who have ever breathed or cried, even if only for a short time.*
- *Do NOT include stillbirths or abortions.*
- *Do NOT include adopted children or children of her husband by another wife.*

*If you cannot obtain the answer to a question,* ***do not leave a blank space*** *- put a 99 in the space provided for the answer.*

**MORTALITY MODULE**

**NGO no. _____ Cluster no. _____ Household no. _____**

**INTERVIEWER:** *If neither the mother of the child nor any of the above-mentioned people are at home, you must visit the household again.*

**Birth Listing Form**

| **Household Member No._____ Woman's Name: _____ _____** | **FOR LIVE BIRTHS ONLY:** | | | | | **Age at Death? (Mos.) (99 DK)** |
|---|---|---|---|---|---|---|
| | **Child's Name: _____ _____** | **Child's HMNo: 99 if not in house** | **Sex: 1 Male 2 Female** | **Date of birth: dy/mo/yr 9 Don't Know (DK)** | **Still alive? 1 Yes 0 No 9 DK** | |
| **Last Live Birth** | | | | | | |
| **Next Last Live Birth** | | | | | | |
| **Second to Last Live Birth** | | | | | | |
| **Twin Live Birth** | | | | | | |

Who answered the above questions? _____

**1** mother of child
**2** mother's own mother
**3** sister living in same household
**4** mother-in-law
**5** husband
**9** other

## BREASTFEEDING and WEANING PATTERNS MODULE

**NGO no. _____ Cluster no. _____ Household no. _____**

**INTERVIEWER:**

- *Ask the questions in this module **only** if there is a child under **age 5** in the dwelling.*
- *Ask the questions of the mother or child caretaker*
- *Ask the questions about the youngest child.*

1. What is the name of your last child? _____

2. Household Member Number of Child (from Household Module): _____

3. Is this child still breastfeeding? _____
   **1** yes ⇨**GO TO QUESTION 5**
   **0** no

4. If no, at what age did this child stop breastfeeding? _____ (months)

5. How many months was this child exclusively breastfed, without water, pop,phala or any other foods besides mother's milk? _____ (months)

6. If this child has been fed breast milk or commercial formula, what was the first supplementary food you gave to your child? (Describe) _____ _____

7. How many times per day did you give this food to this child? _____

## VITAMIN A KNOWLEDGE, ATTITUDE AND PRACTICES MODULE

**NGO no. _____ Cluster no. _____ Household no. _____**

**INTERVIEWER**: *The questions in this module should be asked of one mother or caretaker with at least one child under age 5 in the dwelling. If there is more than one child under age 5, ask the following questions about the oldest child under 5 years.* **I am going to ask you about foods that you and your child frequently eat and illnesses that you sometimes see in this area**.

### Module A
### (for all countries with/planning dietary education programme)

**(A)** In the past 7 days, how many days did [name of child under five] eat the following foods? (List country/region/season-specific target vitamin A food source (example below.)

**99** Don't Know

**(B)** In the past 7 days, how many days did you eat the following foods?

**99** Don't Know

| **Food** | **No. of days/week you / your child eat these foods** | |
|---|---|---|
| | **(A) Child (under five)** | **(B) Mother (15-49 years)** |
| **Household Member No.** | | |
| Milk | | |
| Butter | | |
| Eggs | | |
| Meat | | |
| Fish | | |
| Fortified dry skimmed milk | | |
| Liver | | |
| Kale | | |
| Swiss chard/spinach | | |
| Carrot | | |
| Pumpkin | | |
| Sweet potato | | |
| Papaya | | |
| Mango | | |

**VITAMIN A KNOWLEDGE, ATTITUDE AND PRACTICES MODULE** (cont')

**NGO no. _____ Cluster no. _____ Household no. _____**

A2. Have you ever heard of night blindness (use local term)? _____

**1** yes
**0** no ⇨**If no, GO TO NEXT MODULE**

A3. How is night blindness (local term) caused? _____

**1** food related
**2** water related
**3** don't know
**9** other (describe)_____

A4. Can you tell me 3 foods that prevent night blindness?
(*Prompt for foods from the following 3 categories*.)

Animal foods _____
Fruits _____
Vegetables _____
**99** don't know _____

A5. How do you treat night blindness? _____

**1** animal liver
**2** other foods (specify)
**3** medical
**4** don't know
**9** other

## VITAMIN A KNOWLEDGE, ATTITUDE AND PRACTICES MODULE

**NGO no. _____ Cluster no. _____ Household no. _____**
**Child HM no._____ Mother HM no. _____**

### Module B
### (For countries with/planning supplementation programmes)

B1. Have you ever received a vitamin A capsule like this one for your

(a) last child? _____
(b) yourself? _____

**1** yes
**0** no **If no, ⇨ GO TO NEXT MODULE**
**9** don't know **⇨ GO TO NEXT MODULE**

B2. If yes, how many **months** ago did

(a) your child take the last capsule? _____ (**99** don't know)
(b) you take the last capsule? _____ **(99** don't know)

### Module C
### (For countries with/planning food fortification programme)

**INTERVIEWER:**

- *Please fill out module C for **EACH** fortified food that applies to your programme.*
- *If the fortified food is targeted towards the child (ex. weaning food), ask the questions in this module to the mother, about her child (under 5 years).*
- *If the fortified food is targeted towards the mother (for ex. flour), ask the questions in this module to the mother, about herself.*

C1. We would like to know if some food products are used in your household. Do you have the [fortified food product] in the house? Would you show us?_____

**1** Yes (seen)
**2** Yes (not seen)
**0** No **⇨ If no, GO TO NEXT MODULE**

C2. In the last week, did [your child/you] eat [name of fortified food]?
(*Show product and prompt: used in cooking, etc?*) _____
**1** Yes
**0** No
**9** Don't know

## IODINE KNOWLEDGE, ATTITUDE AND PRACTICES MODULE

**NGO no. _____ Cluster no. _____ Household no. _____ HM no. _____**

**INTERVIEWER**: *This module should be asked to a woman in the dwelling between 15 and 49 years of age.*

### MODULE A

A1. Have you ever seen someone with goitre? _____
**1** yes
**0** no

A2. What is the cause of goitre?
**1** iodine deficiency
**2** food related
**3** contamination of food/water
**4** pregnancy
**5** hereditary
**6** don't know
**9** other (specify) _____

A3. How do you treat goitre?
**1** tatoo
**2** branding
**3** medical
**4** special salt
**5** don't know
**9** other (specify) _____

### MODULE B
### (For countries with/planning supplementation programme)

**INTERVIEWER:** *Show the woman a sample of an iodine capsule/oil.*

B1. Have you ever received a capsule or oil like this? _____
**1** yes
**0** no ⇨ **If no, GO TO NEXT MODULE**

B2. How many months ago did you take the last capsule/oil? _____
**99** Don't know

## IODINE KNOWLEDGE, ATTITUDE AND PRACTICES MODULE

**NGO no. _____ Cluster no. _____ Household no. _____ HM no. _____**

### MODULE C
### (For countries with salt iodization programme)

**INTERVIEWER**: **We would like to check whether the salt used in your household is iodized. May we see a sample of the salt used to cook the main meal eaten by members of your household last night?** *Once you have examined the salt, complete the questions below.*

C1. Record the test outcome: _____

**1** Iodized
**2** Not iodized
**3** No salt in home
**9** Not tested

C2. Record type of salt: _____

**1** Granular (loose)
**2** Salt in bag with seal
**3** Salt in blocks
**4** Not seen
**9** Other _____

## IRON KNOWLEDGE, ATTITUDE AND PRACTICES MODULE

**NGO no. _____ Cluster no. _____ Household no. _____ HM No. _____**

**INTERVIEWER**: *This module should be asked to the mother or caretaker with at least one child under age 5 in the dwelling.* **I am going to ask you about illnesses that you sometimes see in this area.**

### MODULE A

A1. Have you ever heard of anaemia/shortage of blood? _____
**1** Yes
**0** No ⇨ **If no, GO TO QUESTION A4**

A2. Can you tell me how you get shortage of blood? (*Prompt for 3 answers*)

_____
_____
_____

**1** lack of food
**2** illness/disease
**3** bleeding
**4** heavy work
**5** don't know
**9** other (specify)_____

A3. Can you tell me 3 foods that are good for a pregnant woman to eat to prevent shortage of blood/pregnancy anaemia?

_____
_____
_____

**1** meat/fish
**2** eggs
**3** leafy green vegetables
**4** bones
**5** legumes and vitamin C rich foods
**6** don't know
**9** other (specify)_____

A4. If you are pregnant, or when you were last pregnant, did you attend an antenatal clinic (ANC)?
**1** Yes⇨ if yes, **GO TO QUESTION A6**
**0** No

**IRON KNOWLEDGE, ATTITUDE AND PRACTICES MODULE (continued)**

**NGO no. _____ Cluster no. _____ Household no. _____ HM No. _____**

A5. Why did you not attend an (ANC)? _____ ⇨**GO TO QUESTION A7**

**1** Too far to service
**2** Don't think I needed to attend
**3** Don't like the trained staff
**4** Inadequate service (no drugs, no staff, or no delivery equipment/specify) _____

A6. For how many months did you attend an ANC during your last pregnancy? _____

A7. If you are pregnant, or when you were last pregnant, do/did you see a trainedbirth attendant (TBA)? _____
**1** Yes
**0** No

A8. At which month of a pregnancy should women first go to an ANC, or see a TBA? _____

A9. Do you want to have another child in the next two years? _____
**1** Yes
**0** No
**9** Don't Know

A10. Does your husband want to have another child in the next two years? _____
**1** Yes
**0** No
**9** Don't Know

A11. Are you or your husband currently using any method to avoid or postpone getting pregnant? _____
**1** Yes
**0** No ⇨ **If no, GO TO NEXT MODULE**

A12. If yes, specify method _____
**1** traditional
**2** modern pills
**3** modern injection
**4** modern other
**5** don't know
**9** other

**IRON KNOWLEDGE, ATTITUDE AND PRACTICES MODULE (continued)**

**NGO no. _____ Cluster no. _____ Household no. _____ HM no. _____**

**MODULE B**
**(For areas with supplementation programme)**

B1. Have you ever taken drugs or tablets (*like this one - if standard drug distributed in area*) for strengthening blood? _____
**1** Yes
**0** No ⇨ **If no, GO TO B5**

B2. During which pregnancy did you take the last tablets? _____
**1** most recent pregnancy
**2** previous pregnancy
**9** other (specify) _____

B3. When you were taking these tablets during your pregnancy, for how many months did you take the tablets daily as prescribed? _____
**0** none
**1** 1 to 4 months
**2** 5 to 9 months ⇨ **If 2, GO TO QUESTION B5**
**9** don't know

B4. Why were the pills not taken every day as prescribed? _____
**(*Do NOT prompt for answers*)**

**1** clinic or TBA did not give pills on regular basis
**2** pills make her feel sick
**3** she missed appointments at clinic
**4** pills have a bad taste and/or smell
**5** instructions given by TBA or ANC worker were not understood
**9** other (specify) _____

B5. Why do you think that a pregnant woman should take iron/folic pills? _____

**1** increase strength
**2** reduce anaemia/iron deficiency
**3** help baby to be healthy
**4** don't know
**9** other (specify) _____

**IRON KNOWLEDGE, ATTITUDE AND PRACTICES MODULE (continued)**

**NGO no. _____ Cluster no. _____ Household no. _____ HM no. _____**

**MODULE C**
**(For areas with fortification programmes)**

**INTERVIEWER:**

- *Please fill out module C for **EACH** fortified food that applies to your programme.*
- *If the fortified food is targeted towards the child (ex. weaning food), ask the questions in this module to the mother, about her child (under 5 years).*
- *If the fortified food is targeted towards the mother (for ex. flour), ask the questions in this module to the mother, about herself.*

C1. We would like to know if some of the following food products are used in your household. Do you have [fortified food product] in the house? Would you show us?_____

**1** Yes (seen)
**2** Yes (not seen)
**0** No ⇨ **If no, GO TO NEXT MODULE**

C2. In the past week], did (your child/you) eat [name of fortified food]?
*(Show product and prompt: used in cooking, etc?*) _____
**1** Yes
**0** No
**9** Don't know

## IMMUNIZATION, MORBIDITY AND ANTHROPOMETRY MODULE

**INTERVIEWER:** *This module is directed to the mothers or caretakers of all children* ***under age 5*** *in the dwelling. The questions below correspond to the* ***Child Immunization Table****.*

- *Complete the table for all children under 5 years in the dwelling.*
- *Fill in the child's member number, name, and sex from the Household Member Listing Form.*
- *Then ask the mother the following questions, filling in the answers on the Child Immunization Table.*
- *Weigh and measure the child at the end of the interview, after asking all questions and completing all modules.*

4. When was [name of child] born? Day/month/year

5. What is the source of the birthdate information?
   **1** mother
   **2** other relative
   **3** birth card

6. What is the birth weight (kg) of your child on the birth card? None **99**

7. Is there a vaccination record card for [name of child]?
   **1** Yes
   **0** No
   **9** Don't Know

***If an immunization card is available****, copy the dates for each type of immunization on the table (No. 8, 10, 11 and 12):*

- *Copy the dates for only the third dose of DPT and OPV.*
- *If no date for vaccination is recorded on the card, or* ***if no card is available****, use probing questions below to find out if the child received that vaccination, and if so, how many doses.*
- *Record the mother's response for each vaccine in the space provided in the table.*

8. Has [name] ever been given a BCG vaccination against tuberculosis - that is, an injection in the left shoulder that caused a scar?

   **1** Yes
   **0** No

**IMMUNIZATION, MORBIDITY AND ANTHROPOMETRY MODULE (continued)**

10. Has [name] ever been given 'vaccination injections' - that is, an injection in the thigh or buttocks - to prevent him/her from getting tetanus, whooping cough, diphtheria? How many times?
    **1** 3 times(Yes)
    **0** 0, 1 or 2 times (No)
    **9** Don't Know

11. Has [name] ever been given any 'vaccination drops' to protect him/her from getting diseases - that is, polio? How many times has he/she been given these drops?
    **1** 3 times(Yes)
    **0** 0. 1 or 2 times (No)
    **9** Don't Know

12. Has [name] ever been given 'vaccination injections' - that is, a shot in the arm or in the clavicle, at the age of 9 months or older - to prevent him/her from getting measles?
    **1** Yes
    **0** No
    **9** Don't Know

13. Is [name of child] sick today, or was she/he sick in the previous two days?
    **1** Yes
    **0** No ⇨ **If no, GO TO QUESTION 15**

14. If [name of child]is sick, what is she/he sick with?

    **1** fever
    **2** diarrhea (3 or more watery stools per day)
    **3** upper respiratory tract infection (common cold, nasal discharge, cough, oral inflammation)
    **4** lower respiratory tract infection (cough, fast breathing, chest indrawing)
    **5** malaria
    **9** other (oral thrush, ear discharge skin rash infection, dehydration, eye infections, scabies, measles)

    *If the child is not present, ask the mother about the presenting features of the illness so that a diagnosis can be made. If the child is present, have the medical staff member note the presenting features.*

**IMMUNIZATION, MORBIDITY AND ANTHROPOMETRY MODULE**
**(For Children Under 5 Years of Age)**

**NGO No. _____ Cluster No. _____ Household No. _____**
**Interview Date:_____ (dd/mm/yy)**

**Child Immunization Table**

| 1.Household Member No. | | | | |
|---|---|---|---|---|
| 2. Name | | | | |
| 3. Sex<br>1 Male; 2 Female | | | | |
| 4. Birthdate (dd/mm/yy) | | | | |
| 5. Source | | | | |
| 6. Birth Weight (kg) | | | | |
| 7. Vaccination Card | | | | |
| 8. BCG (dd/mm/yy) | | | | |
| 9. BCG Scar<br>1 Yes; 0 No | | | | |
| 10. DPT3 (dd/mm/yy) | | | | |
| 11. OPV3 (dd/mm/yy) | | | | |
| 12. Measles (dd/mm/yy) | | | | |
| 13. Sick | | | | |
| 14. Illness | | | | |
| 15. Weight- kg. | | | | |
| 16. Height-cm | | | | |

**VITAMIN A CLINICAL EXAMINATION MODULE**
**(For all areas with vitamin A interventions)**

**NGO no. _____ Cluster no. ___ Household no.____**

**INTERVIEWER**: *This module is to be filled by an interviewer who is trained to identify xerophthalmia. The following question are **probing** questions to **be asked to all** mothers or caretakers with children between 24 and 71 months of age to determine night blindness for each child. These questions are prompt questions, and do not need to be recorded.*

Does your child have any problem seeing in the daytime?
Does your child have any problem seeing at nighttime?
Yes ⇨ **GO TO QUESTION 3**
No ⇨ **GO TO CLINICAL EXAMINATION SECTION (BITOT'S SPOTS)**
Is this problem any different from other children in your community?
Does your child have night blindness? (*Use local term*) *Record answer on table below*
**1** Yes
**0** No
**9** Don't know

*For **Bitot's spots, corneal dryness, keratomalacia, and corneal scar**, examine all children 6 to 71 months and all women of child-bearing ages (15 to 49 years) in the household.*

| Household Member No. | Name | Vitamin A status 1 Yes 0 No 9 Undetermined | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Night blindness 1 Yes 0 No 9 Don't Know | Bitot's spots | | Corneal dryness | | Keratomalacia | | Corneal scar | |
| | | | L | R | L | R | L | R | L | R |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

## BIOCHEMICAL ASSESSMENT MODULE
## (For all areas with iron and/or vitamin A interventions)

**NGO no. _____ Cluster no. ___ Household no.____**

**INTERVIEWER**: *This module is to be filled by a female technician who is trained to collect breast milk samples, take finger prick samples for haemoglobin determination, and prepare slides for malaria determination.*

*For all areas with **vitamin A interventions**, collect breast milk samples of all lactating women, 1 to 8 months postpartum, in the household. Put the breast milk in a container labelled with date, person number, NGO, cluster and household number. The samples must be stored on ice, under tin foil, transported to the designated laboratory, aliquoted and stored at -20 degrees Celsius until analyzed. Let the mother know that*: **we would like to examine the nutrients in your breast milk to see if your child is getting enough food.**

*For all areas with iron interventions, collect haemaglobin and malaria samples from women of child bearing age (15 to 49 years) and/or for children under 5 years of age (depending on the target group).* **We would like to find the strength of each mother's blood and see if you have malaria, by taking a finger prick sample. We will give you the results of the test and iron capsules today if you or your child need them.**

| House-hold Member No. | Name | Preg-nant<br><br>0 no<br>1Yes<br>9 DK | **Breast Milk Retinol (9 N/A-Child)** | | **Finger Prick** | | |
|---|---|---|---|---|---|---|---|
| | | | 1 Sample obtained<br>2 No milk<br>3 Refused<br>4 Absent | (µmol/l) .25-5.0 | 1 Sample obtained<br>2 Refused<br>3 Absent | Hb (g/dl) 3-20 | MPS<br><br>0 neg<br>1 pos |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

## VILLAGE SURVEY

**NGO no. _____** **Cluster No. _____** **Village no. _____**

**INTERVIEWER:** *Ask the following questions once of the village chief or traditional head of village for each new village surveyed.*

1. What is the pattern of the houses in the village? _____
   **1** Scattered
   **2** Dense
   **3** Villagized (through resettlement programme)

2. Ecological zone: _____

3. What is the size of your village?
   Number of Households
   Number of people

**Agriculture**

4. Is there agriculture extension service? _____
   **1** Yes
   **0** No

5. What is the main crop that is farmed by people in the village? _____
   (country specific)
   **1** Pastorial area
   **2** Cereal
   **3** Cash crop
   **4** Ensete
   **5** Mixed

6. What month(s) are the months of harvest season(s)? _____
   (country specific - following example from Ethiopia)
   **1** Meher
   **2** Belg
   **3** Meher + Belg
   **4** Meher + Belg + other

7. Do you practice irrigation? _____
   **1** Yes
   **0** No

8. Do you use chemical fertilizer? _____
   **1** Yes
   **0** No

## VILLAGE SURVEY (Cont')

**NGO no. _____** **Cluster No. _____** **Village no. _____**

9. Is there a veterinary clinic in your village? _____
   **1** Yes ⇨If yes, **GO TO QUESTION 11**
   **0** No

10. How far is it from your village to the nearest veterinary clinic?
    _____ Kms. **OR**
    _____ Hours Walk (to nearest .5 hr)

**Health**

11. Is there a health facility in your village? _____
    **1** Yes
    **0** No ⇨If no, **GO TO QUESTION 13**

12. What type of health facilities are in the village? ____⇨**GO TO QUESTION 14**
    **1** Community health service
    **2** Health station
    **3** Health centre
    **4** Hospital
    **9** Other (specify):_____

13. If there is no health facility,
    a) How far is it from your village to the nearest Health Facility?
    _____ Kms. **OR**
    _____ Hours Walk (to nearest .5 hr)

    b) What is the type of health facility nearest to the village? _____
    **1** Community health service
    **2** Health station
    **3** Health centre
    **4** Hospital
    **5** Other (specify):_____

**Education**

14. Is there a school in your village? _____
    **1** Yes
    **0** No ⇨If no, **GO TO QUESTION 16**

15. What type(s) of school is in your village? _____⇨**GO TO QUESTION 18**
    (More than one answer is possible)
    **1** Elementary school
    **2** Junior high school
    **3** High school
    **9** Other (specify) _____

## VILLAGE SURVEY (Cont')

**NGO no. _____** **Cluster No. _____** **Village no. _____**

16. If there is no school, how far is from your village to the nearest school?
_____ Kms. **OR**
_____ Hours Walk (to nearest .5 hr)

17. What is the type of school in the village nearest you? _____ (more than one answer can be noted)
**1** Elementary school
**2** Junior high school
**3** High school
**9** Other (specify) _____

**Other**

18. Is there a flour mill in the village? _____
**1** Yes ⇨If yes, **GO TO QUESTION 20**
**0** No

19. How far is it from your village to the nearest mill?
_____ Kms. **OR**
_____ Hours Walk (to nearest .5 hr)

20. What is the main source of water for the village? _____
**1** River
**2** Well (s) (protected)
**3** Well (s) (unprotected)
**4** Protected spring
**5** Unprotected spring
**6** Pond
**7** Pipe
**8** Lake
**9** Other (specify) _____

21. Is there a road passing through the village? _____
**1** Yes
**0** No ⇨If no, **GO TO QUESTION 23**

22. What type of road passes through your village? _____
**1** All weather road
**2** Dry weather road ⇨**GO TO QUESTION 24**

23. How far is it to the nearest road from your village?
a) All weather road:
_____ Kms. **OR**
_____ Hours Walk (to nearest .5 hr)

b) Dry weather road:
_____ Kms. **OR**
_____ Hours Walk (to nearest .5 hr)

**VILLAGE SURVEY (Cont')**

**NGO no. _____** **Cluster No. _____** **Village no. _____**

24. Is there a market place in your village? _____
**1** Yes ⇨If yes, **GO TO NEXT MODULE**
**0** No

25. How far is it from your village to the nearest marketplace?
_____ Kms. **OR**
_____ Hours Walk (to nearest .5 hr)

# E. Comparison between study and excluded children

Table E.1: Characteristics of study and excluded children 24-59 mo by survey year, Ghana

| Characteristic | 2000 | | | | | | | | 2004 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | |
| | N | % | N | % | p-value[1] | N | % | p-value[2] | N | % | N | % | p-value[1] | N | % | p-value[2] |
| **Health and nutrition practices** | | | | | | | | | | | | | | | | |
| Fully immunized | 253 | 77.1 | 175 | 69.7† | 0.088 | 89 | 66.3† | 0.045 | 296 | 84.5 | 191 | 85.3 | 0.791 | 41 | 75.6 | 0.154 |
| Child iron supplements[3] | 248 | 91.9 | 165 | 94.5 | 0.309 | 102 | 91.2 | 0.815 | 296 | 82.8 | 190 | 81.1 | 0.800 | 41 | 70.7 | 0.132 |
| ANC attendance | 247 | 96.8 | 163 | 93.9 | 0.161 | 101 | 93.1 | 0.124 | 296 | 98.6 | 191 | 98.4 | 0.843 | 41 | 97.6 | 0.589 |
| Mosquito net owned | | n/a | | n/a | | | n/a | | 296 | 34.8 | 191 | 36.1 | 0.765 | 41 | 36.6 | 0.822 |
| **Household characteristics** | | | | | | | | | | | | | | | | |
| Maternal education, none/non-formal | 253 | 11.9 | 185 | 27.6 | <0.001 | 106 | 30.2 | <0.001 | 296 | 14.9 | 190 | 15.8 | 0.782 | 37 | 13.5 | 0.827 |
| Farmer household head | 253 | 60.9 | 179 | 69.8 | 0.058 | 104 | 59.6 | 0.814 | | n/a | | n/a | | | n/a | |
| Female household head | 251 | 23.9 | 182 | 23.6 | 0.947 | 104 | 24.0 | 0.979 | 294 | 18.4 | 190 | 27.9 | 0.014 | 40 | 42.5 | <0.001 |
| Reed/grass roof material | 253 | 2.4 | 166 | 17.5 | <0.001 | 106 | 15.1 | <0.001 | 296 | 8.4 | 191 | 10.5 | 0.451 | 41 | 7.3 | 0.806 |
| Collected wood as fuel | 251 | 81.3 | 166 | 83.7 | 0.480 | 106 | 84.9 | 0.381 | 296 | 83.8 | 191 | 83.2 | 0.876 | 40 | 95.0 | 0.061 |
| Own a radio | 253 | 60.9 | 166 | 61.4 | 0.906 | 106 | 44.3 | 0.004 | 296 | 85.1 | 191 | 83.2 | 0.575 | 41 | 75.6 | 0.119 |
| Own a bicycle | 253 | 21.3 | 166 | 21.1 | 0.949 | 106 | 18.9 | 0.597 | 296 | 28.0 | 191 | 27.7 | 0.944 | 41 | 29.3 | 0.870 |
| Own land/has farm | 251 | 87.6 | 165 | 90.3 | 0.403 | 106 | 87.7 | 0.982 | 296 | 87.2 | 191 | 83.2 | 0.229 | 40 | 92.5 | 0.333 |
| Own animals | 253 | 78.3 | 185 | 77.8 | 0.916 | 106 | 70.8 | 0.129 | 295 | 77.6 | 190 | 76.3 | 0.737 | 40 | 85.0 | 0.287 |

*Continued on next page*

Table E1: Characteristics of study and excluded children 24-59 mo by survey year, Ghana, *continued*

| **Characteristic** | **2000** | | | | | | | | **2004** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Study** | | **Excluded (no Hb)** | | | **Excluded (with Hb)** | | | **Study** | | **Excluded (no Hb)** | | | **Excluded (with Hb)** | | |
| | N | % | N | % | p-value[1] | N | % | p-value[2] | N | % | N | % | p-value[1] | N | % | p-value[2] |
| Health facility proximity | | | | | | | | | | | | | | | | |
| In village | 253 | 43.1 | 170 | 37.6 | 0.780 | 103 | 46.6 | 0.569 | 296 | 43.6 | 186 | 39.8 | 0.376 | 38 | 34.2 | 0.103 |
| Within 5 km | | 23.7 | | 25.3 | | | 20.4 | | | 36.8 | | 37.1 | | | 31.6 | |
| Over 5 km | | 33.2 | | 37.1 | | | 33.0 | | | 19.6 | | 23.1 | | | 34.2 | |

[1] P-value associated with chi-square test for difference in proportion between study and all excluded children 24-59 mo.

[2] P-value associated with chi-square test for difference in proportion between study and excluded children 24-59 mo with Hb measurements.

[3] Mother reported receiving iron supplements for her youngest child.

† No evidence for association with study/excluded status when adjusted for child's age. n/a = No data available for this indicator and group of children at this time point.

Table E.2: Characteristics of study and excluded children 24-59 mo by survey year, Malawi

| Characteristic | 2000 | | | | | | | | 2004 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | |
| | N | % | N | % | p-value[1] | N | % | p-value[2] | N | % | N | % | p-value[1] | N | % | p-value[2] |
| **Health & nutrition practices** | | | | | | | | | | | | | | | | |
| Fully immunized | 466 | 86.1 | 231 | 85.3 | 0.749 | 229 | 87.3 | 0.674 | 679 | 97.8 | 358 | 96.4 | 0.385 | 154 | 88.3 | <0.001 |
| Iron supplements[3] | | n/a | | n/a | | | n/a | | 611 | 73.8 | 350 | 70.3 | 0.238 | 164 | 70.7 | 0.429 |
| ANC attendance | 435 | 97.5 | 231 | 99.1 | 0.140 | 221 | 96.8 | 0.636 | 626 | 98.2 | 352 | 99.4 | 0.119 | 167 | 98.8 | 0.613 |
| Private, improved toilet | 466 | 77.0 | 249 | 80.3 | 0.311 | 244 | 82.0 | 0.127 | 679 | 79.7 | 374 | 81.6 | 0.464 | 180 | 75.6 | 0.229 |
| **Household characteristics** | | | | | | | | | | | | | | | | |
| Maternal education, none/non-formal | 466 | 36.1 | 250 | 35.2 | 0.691 | 244 | 32.0 | 0.210 | 679 | 23.6 | 371 | 23.2 | 0.879 | 172 | 23.8 | 0.948 |
| Farmer household head | 466 | 63.9 | 252 | 67.5 | 0.346 | 245 | 60.4 | 0.353 | 677 | 71.6 | 372 | 65.3 | 0.034 | 184 | 72.3 | 0.864 |
| Female household head | 466 | 33.3 | 252 | 27.0 | 0.083 | 245 | 27.8 | 0.133 | 679 | 15.3 | 375 | 10.7 | 0.035 | 186 | 15.6 | 0.927 |
| Reed/grass roof material | 466 | 88.6 | 251 | 92.4 | 0.106 | 245 | 86.5 | 0.415 | 679 | 84.8 | 373 | 90.1 | 0.019 | 185 | 87.0 | 0.479 |
| Collect wood as fuel | 466 | 95.1 | 251 | 94.8 | 0.887 | 245 | 92.2 | 0.130 | 679 | 96.5 | 374 | 96.3 | 0.963 | 184 | 97.8 | 0.313 |
| Owns a radio | 449 | 53.2 | 242 | 51.7 | 0.692 | 238 | 54.6 | 0.728 | 679 | 67.5 | 374 | 71.1 | 0.237 | 185 | 74.1 | 0.092 |
| Owns a bicycle | 449 | 42.5 | 242 | 44.2 | 0.671 | 238 | 48.7 | 0.120 | 679 | 46.8 | 374 | 43.6 | 0.311 | 185 | 48.1 | 0.758 |
| Owns land for cultivation | 466 | 80.9 | 252 | 81.7 | 0.782 | 245 | 84.1 | 0.294 | 671 | 92.3 | 365 | 90.1 | 0.244 | 185 | 90.3 | 0.384 |
| Owns animals | 466 | 68.9 | 251 | 70.9 | 0.573 | 245 | 73.9 | 0.165 | 676 | 72.2 | 374 | 70.6 | 0.572 | 187 | 73.3 | 0.780 |

*Continued on next page*

Table E2: Characteristics of study and excluded children 24-59 mo by survey year, Malawi, *continued*

| Characteristic | | 2000 | | | | | | | 2004 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | |
| | | N | % | N | % | p-value[1] | N | % | p-value[2] | N | % | N | % | p-value[1] | N | % | p-value[2] |
| Health facility proximity | | | | | | | | | | | | | | | | | |
| | In village[4] | 466 | 28.1 | 231 | 35.5 | 0.067 | 202 | 45.5 | <0.001 | 679 | 23.6 | 375 | 20.3 | 0.030 | 187 | 21.4 | 0.606 |
| | <5 km | | 13.9 | | 9.5 | | | 6.4 | | | 51.0 | | 46.7 | | | 55.1 | |
| | >5 km | | 57.9 | | 55.0 | | | 48.0 | | | 25.5 | | 33.1 | | | 23.5 | |
| Region | North | 466 | 15.9 | 252 | 21.4 | 0.149 | 245 | 26.5 | 0.003 | 679 | 18.6 | 375 | 13.6 | <0.001 | 187 | 17.1 | 0.101 |
| | Central | | 19.7 | | 16.7 | | | 17.6 | | | 54.6 | | 42.4 | | | 48.1 | |
| | South | | 64.4 | | 61.9 | | | 55.9 | | | 26.8 | | 44.0 | | | 34.8 | |

[1] P-value associated with chi-square test for difference in proportion between study and excluded children 24-59 mo with no Hb measurement (independent sample).

[2] P-value associated with chi-square test for difference in proportion between study and excluded children 24-59 mo with Hb measurements (independent sample).

[3] Iron supplements received weekly for a child in the household (2004 only).

[4] *In village* = within 30 minutes walk (2000) or within 2 km (2004); *<5 km* = within 1 hr walk (2000) or 2-<6 km (2004); *>5 km* = over 1 hr walk (2000) or ≥6 km (2004)

‡ Evidence for association with study/excluded status, even when adjusted for child age. † No evidence for association with study/excluded status when adjusted for child age.

n/a = No data available for this indicator and group of children at this time point.

Table E.3: Characteristics of study and excluded children 24-59 mo by survey year, Tanzania

| Characteristic | 2000 | | | | | | | | 2004 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | | Study | | Excluded (no Hb) | | | Excluded (with Hb) | | |
| | N | % | N | % | p-value[1] | N | % | p-value[2] | N | % | N | % | p-value[1] | N | % | p-value[2] |
| **Health and nutrition practices** | | | | | | | | | | | | | | | | |
| Fully immunized | 634 | 86.4 | 45 | 71.1 | 0.005 | 176 | 88.1 | 0.571 | 77 | 80.5 | 583 | 74.6 | 0.259 | 169 | 75.1 | 0.354 |
| Iron supplements[3] | | n/a | | n/a | | | n/a | | 69 | 36.2 | 519 | 28.9 | 0.211 | 154 | 35.7 | 0.941 |
| ANC attendance | 630 | 98.4 | 45 | 97.8 | 0.745 | 183 | 98.9 | 0.625 | 75 | 98.7 | 565 | 98.4 | 0.865 | 166 | 99.4 | 0.563 |
| Private/ improved toilet | 634 | 75.6 | 45 | 77.8 | 0.876 | 182 | 77.5 | 0.663 | 77 | 63.6 | 578 | 71.4 | 0.200 | 166 | 66.3 | 0.798 |
| Mosquito bed net owned | 630 | 34.4 | 45 | 31.1 | 0.649 | 184 | 46.7 | 0.002 | 76 | 63.2 | 579 | 46.8 | 0.007 | 167 | 58.1 | 0.455 |
| **Household characteristics** | | | | | | | | | | | | | | | | |
| Maternal education, none/non-formal | 634 | 26.3 | 45 | 24.4 | 0.763 | 184 | 21.7 | 0.206 | 77 | 23.4 | 580 | 24.1 | 0.883 | 167 | 20.4 | 0.593 |
| Farmer household head | 634 | 86.6 | 45 | 88.9 | 0.833 | 184 | 80.4 | 0.051 | 77 | 83.1 | 579 | 79.3 | 0.524 | 169 | 82.8 | 0.957 |
| Female household head | 634 | 10.3 | 45 | 8.9 | 0.770 | 184 | 7.6 | 0.285 | 77 | 6.5 | 584 | 7.7 | 0.705 | 169 | 8.9 | 0.526 |
| Reed/grass roof material | 634 | 70.7 | 45 | 55.6 | 0.050 | 184 | 58.7 | 0.003 | 77 | 55.8 | 584 | 62.2 | 0.345 | 169 | 61.6 | 0.481 |
| Collect wood as fuel | 633 | 94.6 | 45 | 88.9 | 0.132 | 184 | 91.8 | 0.162 | 77 | 93.5 | 584 | 93.0 | 0.864 | 169 | 91.7 | 0.818 |
| Owns a radio | 633 | 46.0 | 45 | 53.3 | 0.339 | 184 | 48.4 | 0.566 | 77 | 55.8 | 582 | 55.0 | 0.886 | 168 | 57.1 | 0.849 |
| Owns a bicycle | 634 | 44.3 | 45 | 35.6 | 0.252 | 184 | 47.3 | 0.477 | 77 | 41.6 | 582 | 47.1 | 0.361 | 167 | 40.7 | 0.901 |
| Owns land or have farm | 630 | 84.7 | 44 | 84.1 | 0.905 | 184 | 82.1 | 0.874 | 76 | 84.2 | 568 | 82.0 | 0.778 | 159 | 84.9 | 0.709 |
| Owns animals | 631 | 60.4 | 45 | 60.0 | 0.960 | 184 | 56.5 | 0.348 | 77 | 57.1 | 575 | 62.8 | 0.338 | 167 | 64.7 | 0.259 |

*Continued on next page*

Table E3: Characteristics of study and excluded children 24-59 mo by survey year, Tanzania, *continued*

| **Characteristic** | **2000** | | | | | | | | **2004** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Study** | | **Excluded (no Hb)** | | | **Excluded (with Hb)** | | | **Study** | | **Excluded (no Hb)** | | | **Excluded (with Hb)** | | |
| | N | % | N | % | p-value[1] | N | % | p-value[2] | N | % | N | % | p-value[1] | N | % | p-value[2] |
| Proximity to health facility[4] | | | | | | | | | | | | | | | | |
| In village | 634 | 73.2 | 45 | 66.7 | 0.607 | 184 | 50.5 | <0.001 | 77 | 28.6 | 529 | 18.9 | 0.054 | 139 | 22.3 | 0.154 |
| Within 5 km | | 16.9 | | 22.2 | | | 35.3 | | | 66.2 | | 69.4 | | | 64.7 | |
| Over 5 km | | 9.9 | | 11.1 | | | 14.1 | | | 5.2 | | 11.7 | | | 12.9 | |

[1] P-value associated with chi-square test for difference in proportion between study and all excluded children 24-59 mo.

[2] P-value associated with chi-square test for difference in proportion between study and excluded children 24-59 mo with Hb measurements.

[3] Specific child received iron supplement regularly (2004 only).

[4] For 2004, distance defined as: *in village* = within 15 minutes walk ; *within 5 km* = within 2 h walk; *over 5 km* = over 2 h walk

‡ Evidence for association with study/excluded status, even when adjusted for child age.

***** When restricted to children with both weight and height data (n=90), underweight prevalence is similar in study and excluded children.

n/a = No data available for this indicator and group of children at this time point.

# F. Variable description and coding

Table F.1 Variable description and coding

| Variable name | Description | Values | Comments |
|---|---|---|---|
| **ChMainID** | Child's unique member ID | e.g. 1_20_1292_04<br>1=Ghana; 2=Tanzania; 3=Malawi<br>20/24=survey year<br>1292=household ID<br>04=household member ID | Unique across all surveys & countries |
| **survyear** | Survey year | 1=2000<br>2=2004 | |
| **Division** | Division ID for Tanzania | 1 = Mombo<br>2 = Mazingara<br>3 = Mzundu<br>4 = Sindeni | Tanzania only |
| **Region** | Region ID for Malawi | 1 = North<br>2 = Central<br>3 = South | Malawi only |
| **hbchild** | Child's haemoglobin level (g/L) | | Adjusted for altitude (Malawi) |
| **anemia3** | Anaemia classification (3 categories) | 0=normal (Hb≥110 g/L)<br>1=mild (100≤Hb<110 g/L)<br>2=moderate/severe (Hb<100 g/L) | |
| **anemia4** | Anaemia classification (4 categories) | 0=normal (Hb≥110 g/L)<br>1=mild (100≤Hb<110 g/L)<br>2=moderate (70≤Hb<100 g/L)<br>3=severe (<70 g/L) | |
| **agemos** | Child's age in months | | |
| **ageclass** | Child's age classification | 1=24-35 mo<br>2=36-47 mo<br>3=48-59 mo | |
| **sexch** | Child's sex | 1=male<br>2=female | |
| **zhaz** | Height-for-age z-score | | WHO 2005 |
| **zwaz** | Weight-for-age z-score | | WHO 2005 |
| **zwhz** | Weight-for-height z-score | | WHO 2005 |
| **stunted2** | Stunting classification | 0=normal (HAZ ≥ -2.0 SD)<br>1=stunted (HAZ < -2.0 SD) | |
| **underwt2** | Underweight classification | 0=normal (WAZ ≥ -2.0 SD)<br>1=underweight (WAZ < -2.0 SD) | |
| **wasted2** | Wasting classification | 0=normal (WHZ ≥ -2.0 SD)<br>1=wasted (WHZ < -2.0 SD) | |
| **malaria** | Malaria classification | 0=negative<br>1=positive | |
| **sick2days** | Child sick in previous 2 days | 0=no<br>1=yes | |

*Continued on next page*

Table F.1 Variable description and coding, *continued*

| Variable name | Description | Values | Comments |
|---|---|---|---|
| **fullimm** | Fully immunized classification | 0=no<br>1=yes | |
| **Chsuppliron** | Mother reports collecting iron supplements for child | 0=no<br>1=yes | N/A for 2000 in Malawi/Tanzania |
| **PotWaterW** | Potable water source classification (wet season) | 0 = not potable<br>1 = potable | |
| **PotWaterD** | Potable water source classification (dry season) | 0 = not potable<br>1 = potable | |
| **Latrine3** | Excreta disposal method classification | 0 = bush, field<br>1 = shared latrine (communal)<br>2 = private, improved latrine (VIP, flush toilet) | Improved includes sanplat in Malawi |
| **KnowAnemia** | Mother reported having heard of anaemia (shortage of blood) | 0 = no<br>1 = yes | |
| **Foodprevanem** | Meat/fish cited as food to prevent anaemia during pregnancy | 0 = no<br>1 = yes | N/A for Tanzania 2000 |
| **ANCattend** | Mother attended ANC during most recent pregnancy | 0 = no<br>1 = yes | |
| **TBAattend** | Mother saw TBA during most recent pregnancy | 0 = no<br>1 = yes | Tanzania: only answered if did not attend ANC |
| **VAC6m** | Youngest child received VAC within last 6 mo | 0=no<br>1=yes | Household-level variable; N/A for Malawi |
| **bednet** | Household has mosquito net | 0 = no<br>1 = yes | N/A for 2000 in Ghana & Malawi |
| **Meatmain** | At least one type of animal raised and its meat products reported to be mainly consumed | 0 = no<br>1 = yes | |
| **Meatconsume3** | Meat consumption level chickens | 1 = no production of animals<br>2 = produce and consume chickens (or one other animal)<br>3 = produce and consume chickens plus at least one other animal | |
| **Chanyliver** | Child liver frequency of intake in the last 7 days | 0 = none<br>1 = at least one day | Tanzania only |
| **Chanymeat** | Child meat + liver frequency of intake in the last 7 days | 0 = none<br>1 = at least one day | Ghana only |
| **Chanymeat24hr** | Child ate any meat, fish, poultry, bush meat or rodents in last 24 hours | 0 = no<br>1 = yes | Malawi only |

*Continued on next page*

Table F.1 Variable description and coding, *continued*

| Variable name | Description | Values | Comments |
|---|---|---|---|
| **MomAge2** | Mother's age classification (2 categories) | 1 = <30 yrs<br>2 = ≥30 yrs | |
| **MomEduc2** | Mother's education classification | 0 = none or non-formal education<br>1 = primary or above | Koran/church is non-formal |
| **MomMarit2** | Mother's marital classification | 0 = other<br>1 = married (mono or poly) | |
| **MomWork2** | Mother's work classification | 0 = other<br>1 = farmer | N/A for GH04 |
| **HeadSex** | Household head's sex | 1 = male<br>2 = female | |
| **HeadEduc2** | Household head's education classification | 0 = none or non-formal education<br>1 = primary or above | Koran/church is non-formal |
| **HeadWork2** | Household head's work classification | 0 = other<br>1 = farmer | N/A for Ghana 2004 |
| **HHmembers** | Number of household members | | |
| **U15number** | Number of members <15yrs | | |
| **Roof2** | Roof material of household | 0 = grass, reed or leaves<br>1 = tin, metal or tile | |
| **Fuel2** | Type of fuel used by household | 0 = collected wood, cow dung<br>1 = purchased wood/charcoal/kerosene | |
| **roomclass** | Number of rooms in house classification | 1 = one room<br>2 = two rooms<br>3 = ≥three rooms | N/A for Ghana |
| **Radio** | Radio owned by household | 0 = no<br>1 = yes | |
| **TV** | TV owned by household | 0 = no<br>1 = yes | N/A for Tanzania |
| **taperec** | Tape recorder owned by household | 0 = no<br>1 = yes | N/A for Tanzania |
| **Bike** | Bicycle owned by household | 0 = no<br>1 = yes | |
| **Mattress** | Mattress owned by household | 0 = no<br>1 = yes | |
| **Lamp** | Lamp owned by household | 0 = no<br>1 = yes | |
| **Improvlamp** | Improved lamp (paraffin or hurricane) owned | 0 = no<br>1 = yes | Tanzania only |
| **Chair** | Chair owned by household | 0 = no<br>1 = yes | |
| **Table** | Table owned by household | 0 = no<br>1 = yes | |

*Continued on next page*

Table F.1 Variable description and coding, *continued*

| Variable name | Description | Values | Comments |
|---|---|---|---|
| **Electric** | Household has electricity | 0 = no<br>1 = yes | |
| **Farm** | Household has farm | 0 = no<br>1 = yes | Ghana & Malawi only |
| **Landownclass** | Land owner classification | 0 = other<br>1 = self | Tanzania only |
| **ownanimals** | Own any animals | 0 = no<br>1 = yes | |
| **WI3by262** | Wealth index rank | 1 = lowest 20%<br>2 = middle 60%<br>3 = highest 20% | |
| **Healthfacility** | Location of nearest health facility | 1 = in community (within 2 km or 30 minutes walk)<br>2 = within 5 km (2 hr walk)<br>3 = over 5 km (2 hr walk) | Distance defined by country |

# G. Wealth Index Characteristics by Country

Table G.1: Ghana wealth index tercile characteristics by survey year[27]

| | 2000 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| **Descriptive statistics** | **Lowest 20%** | **Middle 60%** | **Highest 20%** | **Overall** | **Lowest 20%** | **Middle 60%** | **Highest 20%** | **Overall** |
| N | 60 | 182 | 59 | 301 | 64 | 183 | 67 | 314 |
| Proportion of sample, % | 19.9 | 60.5 | 19.6 | 100.0 | 20.4 | 58.3 | 21.3 | 100.0 |
| Mean score (SD) | 1.42 (0.37) | 0.01 (0.45) | -1.46 (0.41) | 0.00 (1.00) | 1.46 (0.57) | -0.03 (0.39) | -1.31 (0.46) | 0.00 (1.00) |
| Minimum, maximum | 0.95, 2.32 | -0.76, 0.94 | -2.22, -0.85 | | 0.81, 2.88 | -0.69, 0.77 | -2.67, -0.80 | |
| | | | | p-value | | | | p-value |
| *Durable assets owned* | | | | | | | | |
| radio | **28.3** | **62.1** | **81.4** | <0.001 | **48.4** | **91.3** | **100.0** | <0.001 |
| TV | **0** | **3.3** | **74.6** | <0.001 | **1.6** | **3.3** | **65.7** | <0.001 |
| tape recorder | **21.7** | **45.1** | **88.1** | <0.001 | **7.8** | **50.3** | **91.0** | <0.001 |
| bicycle | **8.3** | **23.6** | **28.8** | 0.014 | **14.1** | **31.1** | **31.3** | 0.024 |
| bed with mattress | **76.7** | **96.2** | **100.0** | <0.001 | **82.8** | **95.1** | **100.0** | <0.001 |
| lantern | 98.3 | 97.3 | 91.5 | 0.082 | **100.0** | **98.9** | **92.5** | 0.004 |
| chair | **6.7** | **80.8** | **98.3** | <0.001 | **34.4** | **90.7** | **98.5** | <0.001 |
| table | **35.0** | **94.0** | **100.0** | <0.001 | **46.9** | **96.7** | **100.0** | <0.001 |
| *Housing characteristics* | | | | | | | | |
| Tin roof | **83.3** | **95.1** | **100.0** | <0.001 | **84.4** | **92.3** | **98.5** | 0.011 |
| Has electricity | **6.7** | **23.6** | **86.4** | <0.001 | **6.2** | **15.8** | **88.1** | <0.001 |
| Uses purchased wood/charcoal/ gas | **8.3** | **13.7** | **39.0** | <0.001 | 9.4 | 16.9 | 17.9 | 0.301 |
| *Family characteristics* | | | | | | | | |
| Mom no education | 25.0 | 14.3 | 11.9 | 0.092 | **33.3** | **11.2** | **6.0** | **<0.001** |
| Head no education | 28.3 | 27.5 | 13.6 | 0.079 | **33.3** | **14.4** | **16.4** | **0.004** |
| Akan tribe (majority) | 80.0 | 85.1 | 89.7 | 0.340 | **67.2** | **83.6** | **91.0** | **0.001** |

*Continued on next page*

[27] Terciles developed separately for each survey year, using the 20-60-20 proportion method. Wealth index scores developed using Multiple Correspondence Analysis, including TV ownership.

Table G.1: Ghana wealth index tercile characteristics by survey year, *continued*

| | 2000 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| **Descriptive statistics** | **Lowest 20%** | **Middle 60%** | **Highest 20%** | **Overall** | **Lowest 20%** | **Middle 60%** | **Highest 20%** | **Overall** |
| *Child characteristics* | | | | | | | | |
| Normal Hb | **23.3** | **40.1** | **49.2** | 0.015 | 67.2 | 72.1 | 67.2 | 0.856 |
| Mild anaemia | **21.7** | **25.8** | **18.6** | | 10.9 | 11.5 | 13.4 | |
| Mod/severe anaemia | **55.0** | **34.1** | **32.2** | | 21.9 | 16.4 | 19.4 | |
| Mean Hb, g/L | **98** | **106** | **108** | 0.001 | 113 | 114 | 112 | 0.368 |
| Stunted | 48.3 | 35.7 | 27.1 | 0.052 | 34.4 | 30.1 | 25.4 | 0.531 |
| Malaria positive | 15.6 | 8.9 | 14.3 | 0.331 | **15.6** | **7.3** | **3.2** | **0.031** |
| Sick in last 2 d | 13.3 | 13.2 | 6.8 | 0.392 | 20.3 | 9.9 | 10.4 | 0.080 |
| Fully immunized | 68.3 | 72.0 | 79.7 | 0.356 | 76.6 | 85.2 | 91.0 | 0.067 |

Table G.2: Malawi wealth index tercile characteristics by survey year[28]

| | 2000 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| **Descriptives** | **Lowest 20%** | **Middle 60%** | **Highest 20%** | **Overall** | **Lowest 20%** | **Middle 60%** | **Highest 20%** | **Overall** |
| N | 93 | 311 | 101 | 505 | 148 | 431 | 144 | 723 |
| Proportion of sample, % | 18.4 | 61.6 | 20.0 | | 20.5 | 59.6 | 19.9 | |
| Mean score (SD) | 1.19 (0.13) | 0.15 (0.55) | -1.55 (0.53) | 0.00 (1.00) | 1.21 (0.15) | 0.08 (0.60) | -1.49 (0.41) | 0.00 (1.00) |
| Minimum, maximum | 0.95, 1.33 | -0.90, 0.92 | -3.49, -0.91 | | 0.99, 1.41 | -0.94, 0.99 | -2.77, -0.96 | |
| *Durable assets owned* | | | | p-value | | | | p-value |
| Radio | **7.5** | **54.3** | **86.1** | <0.001 | **25.7** | **73.8** | **93.1** | <0.001 |
| TV | **0** | **0** | **4.0** | <0.001 | **0** | **0.5** | **6.2** | <0.001 |
| tape recorder | **0** | **13.5** | **67.3** | <0.001 | **0** | **8.8** | **45.8** | <0.001 |
| bicycle | **5.4** | **39.2** | **84.2** | <0.001 | **1.4** | **50.3** | **84.0** | <0.001 |
| bed with mattress | **0** | **25.4** | **89.1** | <0.001 | **0** | **32.9** | **88.9** | <0.001 |
| paraffin lamp | **7.5** | **46.9** | **84.2** | <0.001 | **2.7** | **39.9** | **91.7** | <0.001 |
| Chair | **0** | **54.3** | **98.0** | <0.001 | **0** | **45.7** | **96.5** | <0.001 |
| Table | **0** | **35.4** | **98.0** | <0.001 | **0** | **41.3** | **97.9** | <0.001 |
| *Housing characteristics* | | | | | | | | |
| Tin roof | **0.0** | **5.5** | **40.6** | <0.001 | **0.0** | **8.6** | **50.7** | <0.001 |
| Uses purchased wood/ paraffin for cooking | **7.5** | **1.9** | **11.9** | <0.001 | 1.4 | 3.2 | 5.6 | 0.133 |
| People per room, mean | 2.6 | 2.1 | 1.9 | | 3.8 | 3.1 | 2.3 | |
| Has livestock | **57.0** | **69.1** | **80.2** | 0.002 | **50.0** | **74.9** | **86.1** | <0.001 |
| Use private/improved latrine | **58.1** | **77.8** | **86.0** | <0.001 | **64.6** | **81.6** | **89.5** | <0.001 |
| Region | | | | | | | | |
| North | **9.7** | **18.3** | **24.8** | <0.001 | **6.8** | **18.6** | **31.9** | <0.001 |
| Centre | **33.3** | **15.8** | **12.9** | | **77.0** | **52.2** | **36.1** | |
| South | **57.0** | **65.9** | **62.4** | | **16.2** | **29.2** | **31.9** | |
| Mom no education | **47.3** | **35.4** | **21.8** | 0.001 | **38.6** | **23.1** | **11.8** | <0.001 |

*Continued on next page*

[28] Terciles developed separately for each survey year, using the 20-60-20 proportion method. Wealth index scores developed using Multiple Correspondence Analysis, including TV ownership.

Table G.2: Malawi wealth index tercile characteristics, *continued*

| | 2000 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| **Descriptives** | **Lowest 20%** | **Middle 60%** | **Highest 20%** | **Overall** | **Lowest 20%** | **Middle 60%** | **Highest 20%** | **Overal l** |
| Head no education | **41.9** | **19.6** | **10.9** | <0.001 | **21.0** | **10.4** | **4.2** | <0.001 |
| Head works as farmer | **62.4** | **66.9** | **49.5** | 0.007 | **79.5** | **73.5** | **57.7** | <0.001 |
| *Child characteristics* | | | | | | | | |
| Normal Hb | 38.7 | 38.9 | 34.7 | 0.554 | 39.9 | 45.7 | 51.4 | 0.418 |
| Mild anaemia | 24.7 | 19.6 | 26.7 | | 29.1 | 26.5 | 23.6 | |
| Mod/severe anaemia | 36.6 | 41.5 | 38.6 | | 31.1 | 27.8 | 25.0 | |
| Mean Hb, g/L | 105.6 | 103.6 | 104.3 | | 106.5 | 106.4 | 109.8 | |
| Stunted | **65.6** | **60.1** | **45.5** | 0.010 | **64.9** | **53.4** | **45.8** | 0.004 |
| Malaria positive, % | 31.2 | 31.8 | 39.6 | 0.317 | **19.2** | **13.3** | **8.7** | 0.035 |
| Fully immunized, % | 84.9 | 85.2 | 93.1 | 0.110 | 96.6 | 97.4 | 99.3 | 0.290 |
| Sick in prev 2 days, % | 29.3 | 30.0 | 26.0 | 0.744 | 19.6 | 19.5 | 15.3 | 0.505 |
| Child receives iron suppl, % | N/A | | | | 76.2 | 72.6 | 73.3 | 0.731 |

Table G.3: Tanzania wealth index tercile characteristics by survey year[29]

| | 2000 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| **Descriptives** | **Low** | **Middle** | **High** | **Overall** | **Low** | **Middle** | **High** | **Overall** |
| N | 140 | 419 | 139 | 698 | 42 | 128 | 44 | 214 |
| Proportion of sample, % | 20.1 | 60.0 | 19.9 | | 19.6 | 59.8 | 20.6 | |
| Mean score (SD) | 1.30 (0.18) | 0.07 (0.52) | -1.52 (0.42) | 0.00 (1.00) | -1.43 (0.31) | -0.01 (0.51) | 1.42 (0.31) | 0.00 (1.01) |
| Minimum, maximum | 0.95, 1.63 | -0.90, 0.93 | -2.60, -0.93 | | -1.91, -0.95 | -0.94, 0.97 | 1.03, 2.22 | |
| | | | | p-value | | | | p-value |
| *Durable assets owned* | | | | | | | | |
| Radio | 16.4 | 45.9 | 76.3 | <0.001 | 4.8 | 60.9 | 95.5 | <0.001 |
| Bicycle | 23.6 | 42.7 | 70.5 | <0.001 | 11.9 | 35.9 | 76.7 | <0.001 |
| Bed with mattress | 2.1 | 35.6 | 89.9 | <0.001 | 19.0 | 83.5 | 95.5 | <0.001 |
| Chair | 3.6 | 59.2 | 95.7 | <0.001 | 35.7 | 71.9 | 95.3 | <0.001 |
| Table | 2.2 | 71.4 | 96.4 | <0.001 | 14.3 | 74.2 | 100.0 | <0.001 |
| Improved lamp | 0.7 | 15.3 | 74.1 | <0.001 | 0 | 9.4 | 77.3 | <0.001 |
| *Housing characteristics* | | | | | | | | |
| Has electricity | 0 | 0.5 | 5.0 | <0.001 | 0 | 0.8 | 0 | 0.714 |
| Tin roof | 0 | 22.4 | 88.5 | <0.001 | 7.1 | 34.4 | 93.2 | <0.001 |
| Uses purchased wood/ charcoal/ gas | 0 | 2.6 | 20.9 | <0.001 | 0 | 4.7 | 22.7 | <0.001 |
| People per room, mean | 4.6 | 2.8 | 2.0 | | 4.1 | 2.7 | 1.9 | |
| Has livestock | 49.3 | 58.4 | 72.7 | <0.001 | 47.6 | 60.3 | 77.3 | 0.017 |
| Uses private/VIP toilet | 59.7 | 77.5 | 87.8 | <0.001 | 61.0 | 69.3 | 70.5 | 0.082 |
| Mom no education | 43.6 | 24.1 | 14.4 | <0.001 | 35.7 | 21.4 | 11.4 | 0.024 |
| Head no education | 17.1 | 14.6 | 5.0 | 0.005 | 19.0 | 10.9 | 9.1 | 0.296 |
| Head works as farmer | 94.3 | 89.7 | 66.9 | <0.001 | 100.0 | 82.0 | 61.4 | <0.001 |

*Continued on next page*

[29] Terciles developed separately for each survey year, using the 20-60-20 proportion method. Wealth index scores developed using Multiple Correspondence Analysis (not including access to electricity).

Table G.3: Tanzania wealth index tercile characteristics by survey year, *continued*

| | 2000 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| **Descriptives** | **Low** | **Middle** | **High** | **Overall** | **Low** | **Middle** | **High** | **Overall** |
| ADP | | | | | | | | |
| Mazingara | 20.0 | 15.8 | 10.8 | <0.001 | 26.2 | 11.7 | 15.9 | <0.001 |
| Mzundu | 45.7 | 25.8 | 8.6 | | 31.0 | 10.2 | 6.8 | |
| Sindeni | 19.3 | 15.5 | 21.6 | | 19.0 | 14.8 | 13.6 | |
| Mombo | 15.0 | 43.0 | 59.0 | | 23.8 | 63.3 | 63.6 | |
| *Child characteristics* | | | | | | | | |
| Normal Hb | 20.0 | 23.6 | 25.2 | 0.552 | 16.7 | 30.5 | 40.9 | 0.086 |
| Mild anaemia | 18.6 | 22.2 | 23.0 | | 26.2 | 29.7 | 18.2 | |
| Mod/severe anaemia | 61.4 | 54.2 | 51.8 | | 57.1 | 39.8 | 40.9 | |
| Mean Hb, g/L | 96.0 | 96.3 | 98.1 | | 97.2 | 102.3 | 102.5 | |
| Stunted | 73.6 | 66.8 | 51.1 | <0.001 | 61.9 | 47.7 | 36.4 | 0.059 |
| Malaria positive | 10.0 | 9.6 | 13.7 | 0.384 | Insufficient number of children with data | | | |
| Sick in prev 2 days | 58.0 | 53.5 | 54.7 | 0.658 | 35.0 | 32.3 | 29.3 | 0.858 |
| Fully immunized | 77.5 | 88.7 | 90.5 | 0.001 | 79.4 | 89.7 | 94.3 | 0.128 |
| Child receives iron supplement | N/A | | | | 18.8 | 37.0 | 42.9 | 0.081 |

# H. Factors associated with anaemia status – multivariate models by block of variables

Table H.1: Corrected risk ratio estimates (95% CI) of risk factors for anaemia in children 24-59 mo in Ghana (N=549)

| Variable | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | Mild anaemia | Mod/Sev anaemia | Mild anaemia | Mod/Sev anaemia | Mild anaemia | Mod/Sev anaemia |
| **Survey year** | | | | | | |
| 2000 v. 2004 | **2.69** | **2.37** | **2.71** | **2.41** | **2.71** | **2.41** |
| | **(1.89, 3.63)** | **(1.82, 2.96)** | **(1.90, 3.67)** | **(1.85, 3.01)** | **(1.88, 3.70)** | **(1.83, 3.04)** |
| **Proximate variables** | | | | | | |
| Stunted v. Non-stunted | 1.43 | **1.97** | 1.40 | **1.94** | 1.47 | **2.00** |
| | (0.95, 2.04) | **(1.48, 2.50)** | (0.93, 2.02) | **(1.46, 2.47)** | (0.97, 2.13) | **(1.49, 2.55)** |
| Malaria positive v. negative | 1.22 | 1.13 | 1.25 | 1.13 | 1.28 | 1.02 |
| | (0.63, 2.12) | (0.66, 1.76) | (0.65, 2.18) | (0.65, 1.76) | (0.65, 2.24) | (0.56, 1.65) |
| Recent illness yes v. no | 0.80 | **1.57** | 0.74 | 1.52 | 0.71 | 1.46 |
| | (0.39, 1.55) | **(1.05, 2.17)** | (0.34, 1.45) | (0.998, 2.13) | (0.33, 1.41) | (0.94, 2.09) |
| **Intermediary variables** | | | | | | |
| Non-potable water source v. potable | — | — | 0.73 | **0.65** | 0.77 | 0.69 |
| | | | (0.44, 1.17) | **(0.42, 0.98)** | (0.46, 1.23) | (0.44, 1.04) |
| No toilet v. private | — | — | **2.13** | 1.19 | **2.03** | 1.10 |
| | | | **(1.13, 3.48)** | (0.61, 2.03) | **(1.03, 3.40)** | (0.54, 1.95) |
| Shared toilet v. private | — | — | 1.34 | 1.20 | 1.28 | 1.09 |
| | | | (0.87, 1.99) | (0.85, 1.62) | (0.82, 1.92) | (0.75, 1.52) |

*Continued on next page*

Table H.1: Corrected risk ratio estimates (95% CI) of risk factors for anaemia in children 24-59 mo in Ghana (N=549), *continued*

| **Variable** | **Model 1** | | **Model 2** | | **Model 3** | |
|---|---|---|---|---|---|---|
| | **Mild** | **Mod/Sev** | **Mild** | **Mod/Sev** | **Mild** | **Mod/Sev** |
| **Confounding variables** | | | | | | |
| Low wealth rank v. High | — | — | — | — | 1.11 | 1.25 |
| | | | | | (0.53, 2.11) | (0.75, 1.89) |
| Middle wealth rank v. high | — | — | — | — | 1.22 | 0.82 |
| | | | | | (0.70, 2.00) | (0.51, 1.23) |
| Mother no formal education v. some | — | — | — | — | 1.13 | 1.12 |
| | | | | | (0.62, 1.92) | (0.68, 1.70) |
| Health facility over 5 km v. in village | — | — | — | — | 1.62 | **1.93** |
| | | | | | (0.996, 2.46) | **(1.33, 2.60)** |
| Health facility within 5 km v. in village | — | — | — | — | 1.31 | **1.55** |
| | | | | | (0.80, 2.02) | **(1.05, 2.16)** |
| Age 48-59 mo v. 24-35 mo | — | — | — | — | 1.41 | **0.64** |
| | | | | | (0.86, 2.19) | **(0.39, 0.99)** |
| Age 36-47 mo v. 24-35 mo | — | — | — | — | 1.20 | 1.02 |
| | | | | | (0.71, 1.91) | (0.70, 1.41) |
| Female v. Male | — | — | — | — | 1.03 | 1.17 |
| | | | | | (0.68, 1.50) | (0.84, 1.57) |
| Pseudo R-Square (Cox and Snell) | 0.13 | | 0.15 | | 0.20 | |

Model based on N=549, normal: 310 (56.5%); mild 96 (17.5%); moderate/severe 143 (26.0%)

Table H.2: Corrected risk ratio estimates (95% CI) of risk factors for anaemia in children 24-59 mo in Malawi (N=1145)

| Variable | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | **Mild** | **Mod/Sev** | **Mild** | **Mod/Sev** | **Mild** | **Mod/Sev** |
| **Survey year** | | | | | | |
| 2000 v. 2004 | 0.89 | 1.10 | 0.88 | 1.11 | 0.83 | 0.95 |
| | (0.69, 1.14) | (0.92, 1.31) | (0.69, 1.13) | (0.92, 1.33) | (0.61, 1.08) | (0.75, 1.17) |
| **Proximate variables** | | | | | | |
| Stunted v. Non-stunted | 1.23 | **1.38** | 1.22 | **1.39** | 1.22 | **1.40** |
| | (0.98, 1.51) | **(1.17, 1.60)** | (0.98, 1.51) | **(1.17, 1.61)** | (0.97, 1.51) | **(1.18, 1.63)** |
| Malaria positive v. negative | **1.55** | **1.76** | **1.54** | **1.76** | **1.54** | **1.79** |
| | **(1.17, 1.96)** | **(1.49, 2.03)** | **(1.17, 1.96)** | **(1.48, 2.02)** | **(1.17, 1.96)** | **(1.50, 2.05)** |
| Recent illness yes v. no | 1.05 | **1.28** | 1.06 | **1.29** | 1.05 | **1.28** |
| | (0.79, 1.37) | **(1.05, 1.51)** | (0.79, 1.38) | **(1.06, 1.52)** | (0.79, 1.38) | **(1.05, 1.51)** |
| **Intermediary variables** | | | | | | |
| Non-potable water source v. potable | — | — | 1.03 | 1.09 | 1.05 | 1.11 |
| | | | (0.74, 1.39) | (0.85, 1.35) | (0.74, 1.41) | (0.87, 1.38) |
| No toilet v. private | — | — | 1.06 | 0.82 | 1.06 | 0.82 |
| | | | (0.68, 1.57) | (0.55, 1.16) | (0.66, 1.57) | (0.53, 1.17) |
| Shared toilet v. private | — | — | 0.78 | 0.94 | 0.76 | 0.93 |
| | | | (0.53, 1.11) | (0.71, 1.19) | (0.52, 1.10) | (0.70, 1.19) |

*Continued on next page*

Table H.2: Corrected risk ratio estimates (95% CI) of risk factors for anaemia in children 24-59 mo in Malawi (N=1145), *continued*

| Variable | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | Mild | Mod/Sev | Mild | Mod/Sev | Mild | Mod/Sev |
| **Confounding variables** | | | | | | |
| Low wealth rank v. High | — | — | — | — | 0.95 (0.64, 1.36) | 0.93 (0.66, 1.24) |
| Middle wealth rank v. high | — | — | — | — | 0.92 (0.67, 1.22) | 0.99 (0.77, 1.24) |
| Mother no formal education v. some | — | — | — | — | 1.19 (0.91, 1.50) | 1.21 (0.99, 1.43) |
| Health facility over 5 km v. in village | — | — | — | — | 1.01 (0.72, 1.36) | 0.99 (0.79, 1.21) |
| Health facility within 5 km v. in village | — | — | — | — | 0.94 (0.67, 1.26) | **0.76 (0.59, 0.98)** |
| Age 48-59 mo v. 24-35 mo | — | — | — | — | 0.73 (0.52, 1.01) | **0.57 (0.42, 0.75)** |
| Age 36-47 mo v. 24-35 mo | — | — | — | — | 1.01 (0.76, 1.30) | 0.90 (0.73, 1.09) |
| Female v. Male | — | — | — | — | 0.88 (0.69, 1.10) | 0.98 (0.81, 1.16) |
| Pseudo R-Square (Cox and Snell) | 0.05 | | 0.06 | | 0.08 | |

Model based on N=1145, normal: 457 (39.9%); mild 273 (23.8%); moderate/severe 415 (36.2%)

Table H.3: Corrected risk ratio estimates (95% CI) of risk factors for anaemia in children 24-59 mo in Tanzania (N=711)

| Variable | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | Mild anaemia | Mod/Sev anaemia | Mild anaemia | Mod/Sev anaemia | Mild anaemia | Mod/Sev anaemia |
| **Survey year** | | | | | | |
| 2000 v. 2004 | 1.58 (0.82, 3.04) | **1.96 (1.13, 3.40)** | 1.36 (0.69, 2.68) | 1.69 (0.95, 3.01) | 1.30 (0.77, 2.00) | **1.39 (1.05, 1.71)** |
| **Proximate variables** | | | | | | |
| Stunted v. Non-stunted | 1.17 (0.75, 1.83) | 1.22 (0.84, 1.78) | 1.18 (0.75, 1.86) | 1.19 (0.81, 1.74) | 1.14 (0.79, 1.58) | 1.12 (0.93, 1.31) |
| Malaria positive v. negative | 0.56 (0.27, 1.19) | 1.07 (0.62, 1.85) | 0.58 (0.27, 1.22) | 1.10 (0.63, 1.92) | 0.62 (0.31, 1.13) | 1.04 (0.78, 1.29) |
| Recent illness yes v. no | 0.92 (0.59, 1.42) | 1.40 (0.97, 2.03) | 0.93 (0.60, 1.44) | 1.40 (0.97, 2.03) | 0.94 (0.66, 1.29) | 1.16 (0.97, 1.35) |
| **Intermediary variables** | | | | | | |
| Non-potable water source v. potable | — | — | 1.24 (0.80, 1.93) | 0.95 (0.66, 1.38) | 1.18 (0.82, 1.62) | 0.99 (0.81, 1.15) |
| No toilet v. private | — | — | 1.11 (0.45, 2.81) | **2.46 (1.17, 5.20)** | 0.98 (0.45, 1.85) | **1.53 (1.01, 2.01)** |
| Shared toilet v. private | — | — | 0.64 (0.35, 1.17) | 0.83 (0.51, 1.35) | 0.67 (0.39, 1.10) | 0.84 (0.58, 1.15) |

*Continued on next page*

Table H.3: Corrected risk ratio estimates (95% CI) of risk factors for anaemia in children 24-59 mo in Tanzania (N=711), *continued*

| **Variable** | **Model 1** | | **Model 2** | | **Model 3** | |
|---|---|---|---|---|---|---|
| | **Mild anaemia** | **Mod/Sev anaemia** | **Mild anaemia** | **Mod/Sev anaemia** | **Mild anaemia** | **Mod/Sev anaemia** |
| **Confounding variables** | | | | | | |
| Low wealth rank v. High | — | — | — | — | 1.15 (0.63, 1.86) | 1.20 (0.89, 1.48) |
| Middle wealth rank v. high | — | — | — | — | 1.02 (0.64, 1.52) | 1.07 (0.82, 1.30) |
| Mother no formal education v. some | — | — | — | — | 1.23 (0.82, 1.76) | 1.05 (0.84, 1.26) |
| Health facility over 5 km v. in village | — | — | — | — | 0.79 (0.42, 1.36) | 1.06 (0.79, 1.31) |
| Health facility within 5 km v. in village | — | — | — | — | 1.20 (0.73, 1.80) | 1.14 (0.88, 1.36) |
| 48-59 mo v. 24-35 mo | — | — | — | — | 0.88 (0.55, 1.34) | **0.69 (0.51, 0.89)** |
| 36-47 mo v. 24-35 mo | — | — | — | — | 0.81 (0.50, 1.24) | 0.86 (0.68, 1.05) |
| Female v. Male | — | — | — | — | 0.98 (0.69, 1.37) | 1.00 (0.83, 1.18) |
| Pseudo R-Square (Cox and Snell) | 0.03 | | 0.05 | | 0.07 | |

Model based on N=711, normal: 171 (24.1%); mild 160 (22.5%); moderate/severe 380 (53.4%). Note: model not very stable, likely due to low number of cases in 2004 (n=77)

# I. Summary of cross-sectional community-based survey results for children 24-59 mo in sub-Saharan Africa

Table I.1: Summary of cross-sectional community-based survey results for children 24-59 mo in sub-Saharan Africa[1]

| **Country and context** | **Age group** | **Anaemia[2]** | **Mild/mod/severe** | **Mean Hb** | **Other** |
|---|---|---|---|---|---|
| West Africa Region | | | | | |
| Benin national (Ngnie-Teta *et al.*, 2007) | 0-59 mo | 82% | 52% moderate<br>9% severe | | Stunted 34%<br>Recent diarrhea 16% |
| Cote d'Ivoire rural & urban (Asobayire *et al.*, 2001) | 2-5 y | 50% Hb<10;<br>39% IDA | Not reported | 99 | Iron deficiency 63%<br>Malaria 62%<br>Inflammation 46% |
| Equatorial Guinea rural & urban (Custodio *et al.*, 2008) | 0-60 mo[3] | 69% | 8% Hb<80<br>(12% rural vs. 4% urban) | Not reported | Stunted 35% |
| Ghana DHS 2008 rural (Ghana Statistical Service (GSS) *et al.*, 2009) | 6-59 mo[4] | 84% | 22% mild<br>54% moderate<br>9% severe | Not reported | Stunted 32% |
| Ghana DHS 2003 rural (Ghana Statistical Service (GSS) *et al.*, 2004) | 6-59 mo[5] | 80% | 22% mild<br>52% moderate<br>7% severe | Not reported | Stunted 35% |
| Ghana northern rural & town (Ehrhardt *et al.*, 2006) | 6 m – 9 y | 64% | 4% Hb <70 | 101 (U5, dry)<br>93 (U5, rainy) | Malaria 49% dry, 57% rainy |
| Ghana northern rural (Koram *et al.*, 2003) | Data for 2-5 y | | <1% Hb<60 (low)<br>2.8% Hb<60 (high) | | Malaria 51% (low) & 77% (high season) |
| Ghana urban (Klinkenberg *et al.*, 2006) | 6-60 mo | 47%<br>(51 & 43%) | Not reported | 108 & 111 | Malaria 15 & 9% |
| Ghana peri-urban (Ronald *et al.*, 2006) | 1-9 y | A: 35%<br>B: 66% | A: 2% Hb<80<br>B: 3% Hb<80 | A: 113<br>B: 105 | Stunted 7% (A); 21% (B)<br>Malaria 13% (A); 38% (B) |

*Continued on next page*

Table H.1: Summary of cross-sectional community-based survey results for children 24-59 mo in sub-Saharan Africa, *continued*

| **Country and context** | **Age group** | **Anaemia**[1] | **Mild/mod/severe** | **Mean Hb** | **Other** |
|---|---|---|---|---|---|
| Mali national (Ngnie-Teta *et al.*, 2007) | 0-59 mo | 83% | 53% moderate<br>12% severe | | Stunted 42%<br>Recent diarrhea 23% |
| Togo districts (Eliades *et al.*, 2006) | 9 m – 5 y | 84% | 22% Hb<80<br>0.5% Hb<50 | | Malaria 62% |
| East Africa Region | | | | | |
| Ethiopia rural (Adish *et al.*, 1999) | 6-60 mo | 42% | not reported | Ht 35.4±4.8% | Malaria 0%<br>Hookworm 0.4% |
| Ethiopia rural (Deribew *et al.*, 2010) | 0-59 mo | 29-36% | 1-2% severe | | Malaria 8-11% |
| Kenya lowlands & highlands (Akhwale *et al.*, 2004) | 0-5 y | 34% (low)<br>12% (high) | Not reported | | Malaria 26-31%<br>Hookworm 3.9% |
| Kenya coast (Brooker *et al.*, 1999) | 6-76 mo | 76% | 3% Hb<50 | 95.9 | Hookworm 29%<br>Malaria 34% |
| Kenya rural (Verhoef *et al.*, 2001) | 2-36 mo | 69%;<br>46% IDA | 7% Hb<80 | 102.1 | Iron deficiency 42%<br>Malaria 18%<br>Hookworm 0%<br>Inflammation 38% |
| Kenya rural (Desai *et al.*, 2005) | 0-36 mo | 76%<br>71% | 11% Hb<70<br>8% Hb<70 | Graphical form | Malaria 57%<br>Hookworm 8.0% |
| Kenya rural (Friedman *et al.*, 2005b) | 0-36 mo | 71% | 8% Hb<70 | N/A | Stunted 25%<br>Malaria 52%<br>Hookworm 8% |

*Continued on next page*

Table H.1: Summary of cross-sectional community-based survey results for children 24-59 mo in sub-Saharan Africa, *continued*

| **Country and context** | **Age group** | **Anaemia**[1] | **Mild/mod/severe** | **Mean Hb** | **Other** |
|---|---|---|---|---|---|
| Tanzania HMIS 2007-08 (Tanga Region)<br>(Tanzania Commission for AIDS (TACAIDS) *et al.*, 2008) | 6-59 mo | N/A | 8% Hb<80 | N/A | Malaria 14% |
| Tanzania DHS 2004 (Tanga Region) (National Bureau of Statistics Tanzania & ORC Macro, 2005) | 6-59 mo | 66% | 27% mild<br>36% moderate<br>2% severe | | Stunted 43% |
| Tanzania rural (Premji *et al.*, 1995) | 6-40 mo | 74% (Ht<33%) | 3% Ht<20% (severe anaemia) | | |
| Tanzania districts (Schellenberg *et al.*, 2003) | 0-59 mo | 87% | 39% Hb<80<br>3% Hb<50 | | Sick in past 2wks 53% |
| Tanzania rural (Tatala *et al.*, 1998) | 6-59 mo | 84% | 16% mild<br>52% moderate<br>15% severe | 90 | Stunted 57%<br>Malaria 34%<br>Hookworm 4% |
| Zanzibar rural (Stoltzfus *et al.*, 2000) | 4-71 mo | 80% Hb<100 | 16% Hb<70 | For 24-59m:<br>88-92 | For 24-59m:<br>Malaria 79-92%<br>Hookworm 42-77% |
| Southern Africa Region | | | | | |
| Malawi districts<br>(Mathanga *et al.*, 2010) | 6-30 mo | 77-78% | 15-18% Hb<80 | 97-101 | Malaria 17-19% |
| Malawi DHS 2004 rural (National Statistical Office (Malawi) & ORC Macro, 2005) | 6-59 mo | 74% | 27% mild<br>42% moderate<br>5% severe | | Stunted 49% |

*Continued on next page*

Table H.1: Summary of cross-sectional community-based survey results for children 24-59 mo in sub-Saharan Africa, *continued*

[1] Only DHS surveys in Ghana, Malawi and Tanzania are included in this summary

[2] Hb<110 g/L unless otherwise specified

[3] For children 24-60 mo nationally, 68% had Hb<110 and 8% had Hb<80; 46% were stunted.

[4] Using data in table for ages 24-59 mo nationally, overall anaemia is 74.8%, mild 24.3%, moderate 44.2% and severe 6.2%.

[5] Using data in table for ages 24-59 mo nationally, overall anaemia is 73.2%, mild 24.6%, moderate 45.0% and severe 3.6%.