

Neighbourhood Income and Neonatal, Postneonatal and Sudden Infant Death Syndrome (SIDS) Mortality in Canada, 1991-2005

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ABSTRACT

BACKGROUND: Rates of infant mortality declined in Canada in the 1990s and 2000s, but the extent to which all socio-economic levels benefitted from this progress is unknown.

OBJECTIVES: This study investigated differences and time trends in neonatal, postneonatal and sudden infant death syndrome (SIDS) mortality across neighbourhood income quintiles among live births in Canada from 1991 through 2005.

METHODS: The Canadian linked live birth and infant death file was used, excluding births from Ontario, Yukon, Northwest Territories and Nunavut. Mortality rates for neonatal, postneonatal and sudden infant death syndrome (SIDS) were calculated by neighbourhood income quintile and period (1991-1995, 1996-2000, 2001-2005). Hazard ratios (HR) for neighbourhood income quintile and period were computed, adjusting for province of residence, maternal age, parity, infant sex and multiple birth.

RESULTS: In urban areas, for the entire study period (1991-2005), the poorest neighbourhood income quintile had a higher hazard of neonatal death (adjusted HR 1.24, 95% CI 1.15-1.34), postneonatal death (adjusted HR 1.58, 95% CI 1.41-1.76) and SIDS (adjusted HR 1.83, 95% CI 1.49-2.26) compared to the richest quintile. Postneonatal and SIDS mortality rates declined by 37% and 57%, respectively, between 1991-1995 and 2001-2005 whereas no significant change was observed in neonatal mortality. The decrease in postneonatal and SIDS mortality rates occurred across all income quintiles.

CONCLUSION: This study shows that despite a decrease in infant mortality and SIDS across all neighbourhood income quintiles over time in Canada, socio-economic inequalities persist. This finding highlights the need for effective infant health promotion strategies in vulnerable populations.

KEY WORDS: Infant mortality; social class; sudden infant death

La traduction du résumé se trouve à la fin de l'article.

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Infant mortality declined in Canada from 6.5 per 1,000 live births in 1991 to 5.1 in 2000¹ and 5.0 in 2007.² However, the extent to which all socio-economic levels benefitted from this decline is unknown.

Low socio-economic status is associated with a higher risk of adverse perinatal health outcomes, particularly infant mortality.^{3,4} In Canada, findings vary by province and depend on the particular indicator used. In Nova Scotia, low family income is associated with a higher risk of postneonatal, but not neonatal mortality.⁵ In Québec, low maternal education and low neighbourhood income are associated with higher risks of both neonatal and postneonatal mortality, and the association between maternal education and infant mortality remains statistically significant after adjustment for covariates (including neighbourhood income quintile), while the association between neighbourhood income and infant mortality is no longer significant after adjustment for covariates (including maternal education).⁶ In British Columbia, low neighbourhood income is associated with a higher risk of postneonatal mortality in urban but not rural areas, although the association is no longer statistically significant after adjustment for covariates.⁷ Thus the nature and extent of the association between indicators such as neighbourhood income and infant mortality in Canada remain unclear, and time trends in infant mortality within socio-economic strata have not been investigated.

Among causes of death, country-level data are of particular interest for sudden infant death syndrome (SIDS) because of widespread education efforts undertaken through the “back to sleep” campaign in Canada.⁸ Although SIDS rates declined in Canada between 1985 and 2005,^{9,10} trends over time by socio-economic strata have not been examined. In Québec urban areas between 1991 and 2000, poorer neighbourhoods had a higher risk of SIDS relative to richer neighbourhoods, but the low number of SIDS deaths led to statistically non-significant associations, and time trends were not examined.⁴

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Table 1. Infant Mortality in Canada (Excluding Ontario and Territories), 1991-2005

	Live Births	Neonatal Mortality			Postneonatal Mortality			SIDS		
		Rate per 1,000 Live Births	Unadjusted Hazard Ratio (95% CI)		Rate per 1,000 Neonatal Survivors	Unadjusted Hazard Ratio (95% CI)		Rate per 1,000 Live Births	Unadjusted Hazard Ratio (95% CI)	
Total	3,173,694	3.71			1.70			0.53		
Neighbourhood income quintile										
1 (poorest)	753,143	4.14	1.22	(1.16-1.30)	2.54	1.95	(1.79-2.14)	0.86	2.53	(2.16-2.96)
2	650,605	3.72	1.10	(1.03-1.17)	1.64	1.26	(1.14-1.39)	0.53	1.56	(1.31-1.86)
3	621,244	3.69	1.09	(1.02-1.16)	1.46	1.13	(1.02-1.25)	0.44	1.29	(1.07-1.55)
4	607,563	3.46	1.02	(0.96-1.09)	1.33	1.02	(0.92-1.14)	0.35	1.02	(0.84-1.25)
5 (richest)	541,139	3.38		Reference	1.30		Reference	0.34		Reference
Area of residence										
Urban	2,414,309	3.56		Reference	1.53		Reference	0.47		Reference
Rural and small town	759,385	4.17	1.17	(1.12-1.22)	2.25	1.48	(1.39-1.56)	0.69	1.46	(1.32-1.62)
Year of birth										
1991-1995	1,144,957	3.84		Reference	2.10		Reference	0.75		Reference
1996-2000	1,031,217	3.59	0.93	(0.89-0.97)	1.62	0.77	(0.72-0.82)	0.46	0.61	(0.55-0.68)
2001-2005	997,520	3.68	0.96	(0.91-1.00)	1.33	0.63	(0.59-0.68)	0.33	0.44	(0.38-0.49)

The objective of this study was to investigate differences and time trends in neonatal, postneonatal and SIDS mortality across neighbourhood income quintiles in Canada.

METHOD

We used data from the Canadian linked live birth and infant death file created by Statistics Canada through probabilistic linkage of birth and death registrations.¹¹ Births from 1991 through 2005 were included, except those from Ontario because of previously documented concerns related to the completeness of birth registrations,¹² and those from the three territories (Yukon, Northwest Territories and Nunavut) because of a high proportion (27%) of missing postal codes. Births with non-residential postal codes were also excluded.

Maternal residential address at birth was linked to neighbourhood-level income quintile (based on family income adjusted for family size and area of residence, as in previous studies^{6,7} for the Canadian census closest to the birth year (1991, 1996, 2001 or 2006) using Statistics Canada’s Postal Code Conversion File Plus.¹³ Adjustment of income for family size and area of residence gives a better indicator of income adequacy in relation to need, since a family of four requires more resources than a family of two, and housing costs vary widely across Canada.

Neighbourhoods were defined at the lowest level for which census population characteristics were released: enumeration areas for the 1991 and 1996 censuses, and dissemination areas for the 2001 and 2006 censuses. Because neighbourhood income is a less valid marker of socio-economic status in small towns and rural areas (since rich and poor people are more likely to share postal codes), analyses were conducted separately for urban areas and for small towns and rural areas. Urban areas were defined as census metropolitan areas or census agglomerations (population 10,000 or more), while small towns and rural areas included all other areas.¹⁴

Study outcomes included neonatal death (0-27 days), postneonatal death (28-364 days), and SIDS (0-364 days), defined as codes 798.0 and R95 of the ninth and tenth revisions, respectively, of the International Classification of Diseases (ICD-9 and ICD-10). Starting in 2000, ICD-10 was used for coding the underlying cause of death in Canada.

Neonatal and SIDS mortality rates were computed using live births in the denominator, while the denominator for postneonatal mortality rates was the number of infants at risk (infants who

had survived 28 days or more). Rates were calculated for the entire population and study period, by 5-year periods (1991-1995, 1996-2000, 2001-2005) and by quintiles of neighbourhood income (based on Census data). Changes in rates between 1991-1995 and 2001-2005 were expressed as differences in deaths per 1,000 live births or infants at risk and as percentages of the 1991-1995 rate.

Hazards ratios (HR) and 95% confidence intervals (CI) were determined by Cox proportional hazards models using days survived as the time axis. Infants were followed for 364 days from the time of birth, at which point follow-up ended. Unadjusted HRs and HRs adjusted (aHR) for province of residence, maternal age (<20, 20-29, 30-34, and ≥35 years), parity (1, 2, 3, or ≥4 live births, including the current birth), infant sex, and multiple birth (yes, no) were estimated by neighbourhood income quintile and period of birth. No adjustment was undertaken for gestational age, a potential intermediate on the pathway between socio-economic status and infant death.¹⁵ Robust sandwich estimators were used to adjust standard errors for clustering of births in dissemination areas.¹⁶ We used Cox models as they allow us to easily test the possibility that HRs vary with age of infants at time of death, which would be the case if hazards were non-proportional (i.e., if the assumption of proportional hazards was rejected). The proportionality of hazards was verified by log (-log survival) plots. HRs that are proportional are interpreted in a similar manner as relative risks averaged over the follow-up period.¹⁷

Analyses were carried out using SAS 9.1.

RESULTS

Of 3,258,394 live births in the nine study provinces from 1991 to 2005, 3,173,694 (97.4%) were retained in our analyses. The remaining 2.6% were excluded because of missing, invalid or non-residential postal codes. Among the included births, there were 11,765 neonatal, 5,379 postneonatal, and 1,668 SIDS deaths, corresponding to mortality rates of 3.7 per 1,000 live births, 1.7 per 1,000 neonatal survivors, and 0.52 per 1,000 live births, respectively, over the entire study period. Among SIDS deaths, 93.0% occurred in the postneonatal period.

Higher rates of neonatal, postneonatal and SIDS deaths were observed in the two poorest neighbourhood income quintiles compared with the two richest quintiles (Table 1). Infants whose mothers resided in small towns and rural areas were also at higher risk of death compared to infants whose mothers resided in urban areas.

Table 2. Infant Mortality in Urban Areas of Canada (Excluding Ontario and Territories), 1991–2005

	Live Births	Neonatal Mortality			Postneonatal Mortality			SIDS		
		Rate per 1,000 Live Births	Unadjusted Hazard Ratio (95% CI)	Adjusted Hazard Ratio* (95% CI)	Rate per 1,000 Neonatal Survivors	Unadjusted Hazard Ratio (95% CI)	Adjusted Hazard Ratio* (95% CI)	Rate per 1,000 Live Births	Unadjusted Hazard Ratio (95% CI)	Adjusted Hazard Ratio* (95% CI)
Total	2,414,309	3.56			1.53			0.47		
Neighbourhood income quintile										
1 (poorest)	569,279	4.04	1.25 (1.16-1.34)	1.24 (1.15-1.34)	2.24	1.96 (1.76-2.19)	1.58 (1.41-1.76)	0.80	2.76 (2.26-3.37)	1.83 (1.49-2.26)
2	501,546	3.65	1.13 (1.04-1.22)	1.14 (1.05-1.24)	1.55	1.36 (1.21-1.53)	1.20 (1.07-1.35)	0.50	1.71 (1.38-2.12)	1.32 (1.06-1.65)
3	476,071	3.50	1.08 (1.00-1.17)	1.09 (1.01-1.18)	1.34	1.18 (1.04-1.33)	1.07 (0.94-1.20)	0.42	1.43 (1.13-1.80)	1.17 (0.92-1.48)
4	465,752	3.22	0.99 (0.92-1.08)	1.01 (0.93-1.09)	1.15	1.01 (0.89-1.14)	0.96 (0.84-1.08)	0.26	0.89 (0.69-1.15)	0.80 (0.62-1.04)
5 (richest)	401,661	3.24	Reference	Reference	1.14	Reference	Reference	0.29	Reference	Reference
Year of birth										
1991-1995	861,835	3.69	Reference	Reference	1.92	Reference	Reference	0.70	Reference	Reference
1996-2000	781,476	3.42	0.93 (0.88-0.98)	0.90 (0.85-0.95)	1.41	0.73 (0.68-0.79)	0.74 (0.69-0.80)	0.40	0.57 (0.49-0.65)	0.58 (0.50-0.67)
2001-2005	770,998	3.56	0.97 (0.92-1.02)	0.92 (0.87-0.97)	1.20	0.62 (0.58-0.68)	0.65 (0.60-0.70)	0.30	0.43 (0.37-0.50)	0.46 (0.40-0.54)

* Adjusted for neighbourhood income quintile, province of residence at birth, year of birth (5-year interval), parity, sex, and multiple birth.

Table 3. Infant Mortality in Rural Areas of Canada (Excluding Ontario and Territories), 1991–2005

	Live Births	Neonatal Mortality			Postneonatal Mortality			SIDS		
		Rate per 1,000 Live Births	Unadjusted Hazard Ratio (95% CI)	Adjusted Hazard Ratio* (95% CI)	Rate per 1,000 Neonatal Survivors	Unadjusted Hazard Ratio (95% CI)	Adjusted Hazard Ratio* (95% CI)	Rate per 1,000 Live Births	Unadjusted Hazard Ratio (95% CI)	Adjusted Hazard Ratio* (95% CI)
Total	759,385	4.17			2.25			0.69		
Neighbourhood income quintile										
1 (poorest)	183,864	4.45	1.17 (1.05-1.31)	1.14 (1.02-1.28)	3.47	1.98 (1.68-2.33)	1.54 (1.31-1.82)	1.05	2.16 (1.66-2.79)	1.54 (1.19-2.00)
2	149,059	3.93	1.03 (0.92-1.16)	1.03 (0.92-1.16)	1.92	1.09 (0.91-1.31)	1.02 (0.85-1.23)	0.65	1.34 (0.98-1.82)	1.19 (0.87-1.64)
3	145,173	4.31	1.14 (1.01-1.27)	1.15 (1.02-1.29)	1.87	1.06 (0.89-1.28)	1.02 (0.85-1.23)	0.52	1.07 (0.78-1.48)	1.00 (0.72-1.37)
4	141,811	4.27	1.12 (1.00-1.26)	1.13 (1.01-1.27)	1.92	1.09 (0.91-1.31)	1.08 (0.90-1.29)	0.64	1.32 (0.96-1.80)	1.28 (0.93-1.75)
5 (richest)	139,478	3.80	Reference	Reference	1.76	Reference	Reference	0.49	Reference	Reference
Year of birth										
1991-1995	283,122	4.32	Reference	Reference	2.63	Reference	Reference	0.93	Reference	Reference
1996-2000	249,741	4.10	0.95 (0.87-1.03)	0.92 (0.85-1.00)	2.26	0.86 (0.77-0.96)	0.87 (0.77-0.98)	0.67	0.72 (0.59-0.88)	0.74 (0.61-0.90)
2001-2005	226,522	4.06	0.94 (0.86-1.02)	0.90 (0.82-0.98)	1.78	0.68 (0.60-0.77)	0.70 (0.61-0.79)	0.42	0.46 (0.36-0.58)	0.46 (0.36-0.59)

* Adjusted for neighbourhood income quintile, province of residence at birth, year of birth (5-year interval), parity, sex, and multiple birth.

† Adjusted for neighbourhood income quintile, province of residence at birth, year of birth (5-year interval), parity, and sex.

In urban areas, differences in mortality rates across neighbourhood income quintiles were more pronounced. Relative to the richest quintile, the poorest had aHRs of 1.24, 1.58, and 1.83 for neonatal mortality, postneonatal mortality and SIDS, respectively (Table 2).^{*} Except for neonatal mortality, similar but weaker associations were found in small towns and rural areas, where the association between neighbourhood income and SIDS was statistically non-significant after adjustment for covariates (Table 3).^{*} There was little evidence that hazards were non-proportional, suggesting that the magnitude of the association between neighbourhood income and SIDS varied little with age at time of death.

Between 1991-1995 and 2001-2005, rates of neonatal mortality, postneonatal mortality and SIDS in urban areas (all neighbourhood income quintiles combined) declined by 3%, 38% and 57%, respectively.

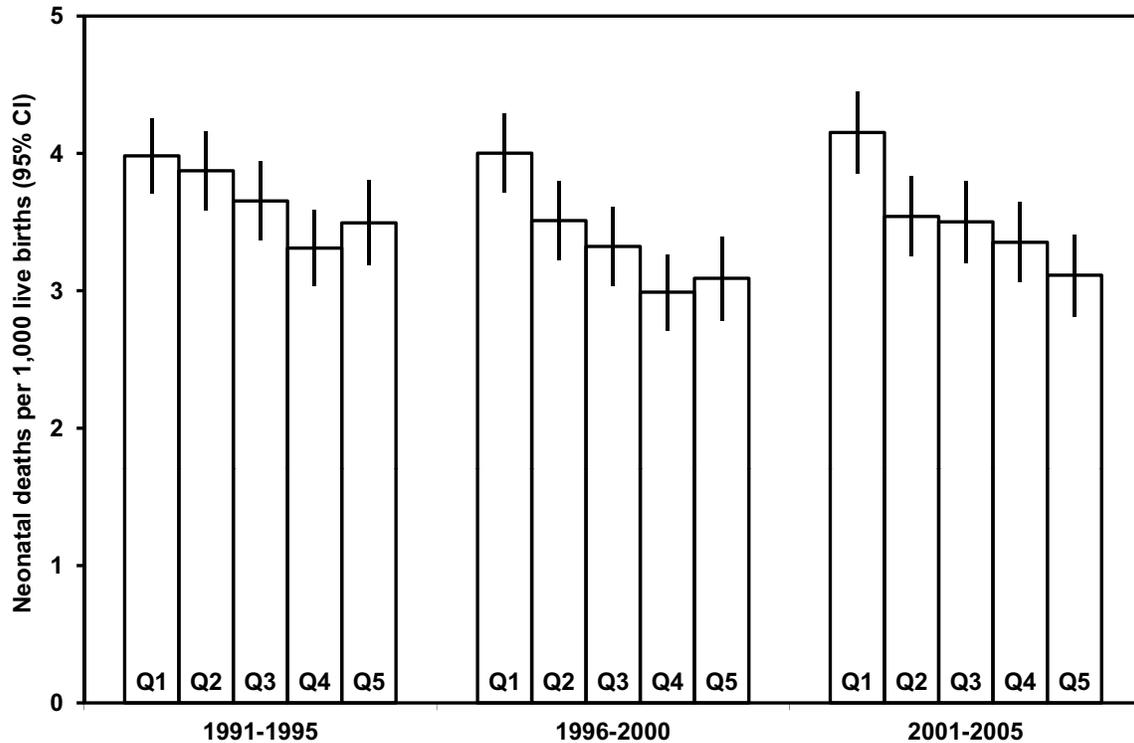
Changes over time in neonatal, postneonatal and SIDS mortality by neighbourhood income quintiles are shown in Figures 1-3. The decrease in rates of postneonatal mortality and SIDS occurred across all income quintiles. Most of the decrease for SIDS took place between 1991-1995 and 1996-2000, while the decrease for postneonatal mortality continued from 1996-2000 to 2001-2005. Over the entire study period, postneonatal mortality rates declined by 35% in the poorest quintile and 39% in the richest quintile. For SIDS, the poorest quintile experienced a 56% decline and the richest quintile a 67% decline, but the absolute decrease in rates was greatest in the poorest quintile.

DISCUSSION

We found that socio-economic inequalities in infant mortality, meas-

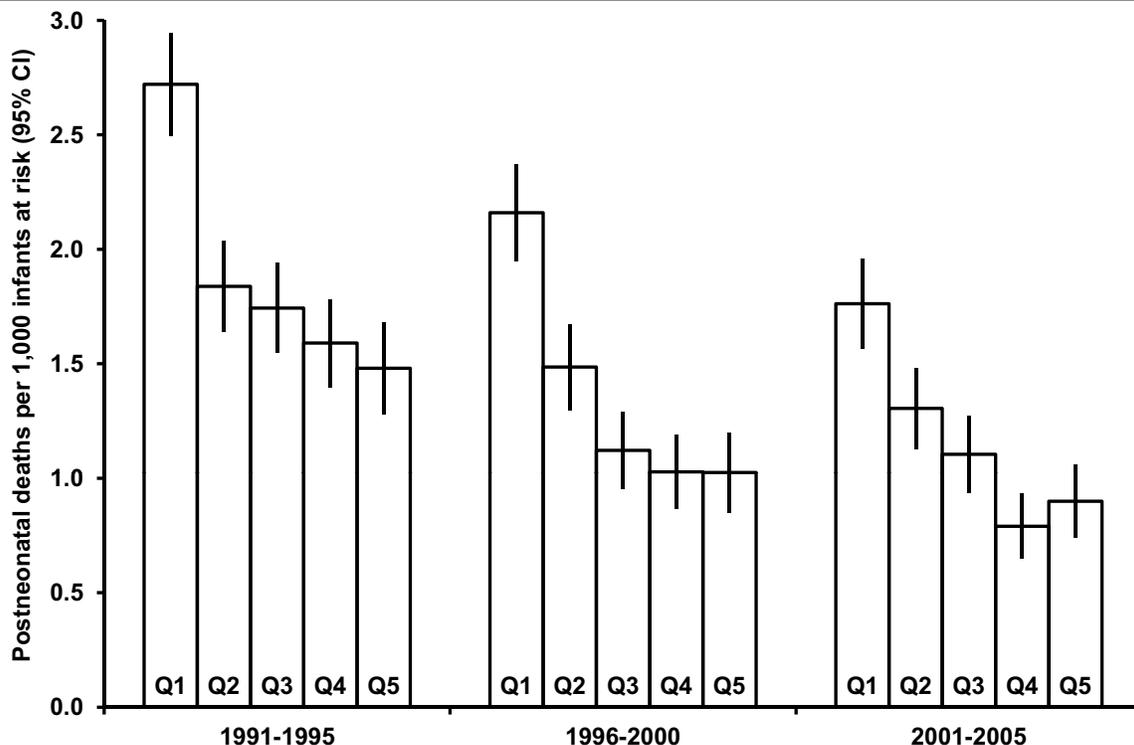
^{*} For more complete data for Tables 2 and 3, please see Supplemental Appendix A and Supplemental Appendix B, respectively.

Figure 1. Neonatal mortality in urban areas of Canada (excluding Ontario and territories) by period and neighbourhood income quintile



Q1 represents the poorest income quintile and Q5 the richest.

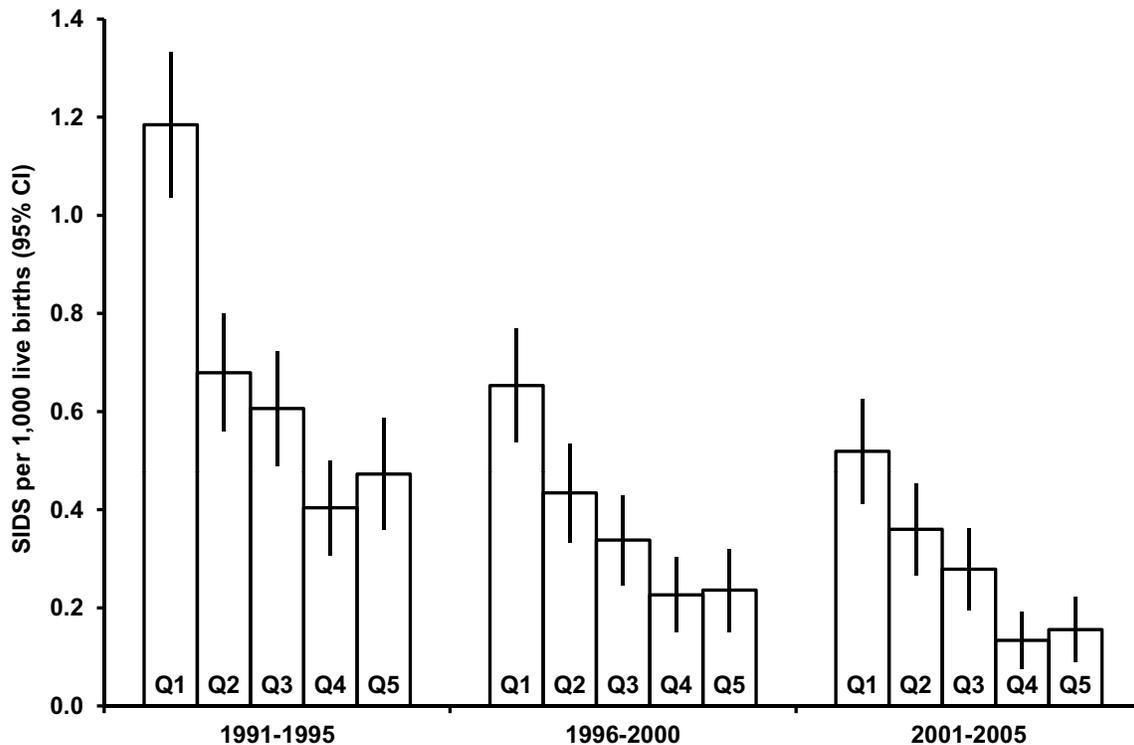
Figure 2. Postneonatal mortality in urban areas of Canada (excluding Ontario and territories) by period and neighbourhood income quintile



Q1 represents the poorest income quintile and Q5 the richest.

ured using neighbourhood income, have narrowed in Canada over a 15-year period but have not disappeared. However, all income quintiles experienced a decline in infant mortality. Unlike previous studies,^{6,7} the

association between neighbourhood income and infant mortality in our study remained statistically significant after adjustment for covariates, most likely due to the greater statistical power of our larger dataset.

Figure 3. Rate of SIDS in urban areas of Canada (excluding Ontario and territories) by period and neighbourhood income

Q1 represents the poorest income quintile and Q5 the richest.

Reasons why low socio-economic status is associated with infant mortality need further investigation, but higher prevalence of risk factors associated with infant death is likely involved. In Canada, mothers who do not complete high school have significantly higher rates of smoking and alcohol use during pregnancy and lower rates of breastfeeding than women with higher levels of education.⁹ In addition, lower maternal education is associated with higher risks of preterm¹⁸ and small-for-gestational-age birth.¹⁹ These inequalities in outcomes were stable or increased over time.^{18,19}

In the poorest neighbourhood income quintile, aHRs were higher for SIDS than for neonatal and overall postneonatal death, indicating that socio-economic gradients in relative risks are more important for SIDS than for other types of infant death. The high hazard ratio of SIDS for lower socio-economic strata is consistent with observations from the United Kingdom, where both unemployment and area deprivation were associated with a higher risk of SIDS.^{20,21} In Canada, the proportion of mothers placing their infants on their back to sleep (the safest position for SIDS prevention)²² increases with higher maternal education.²³ Maternal smoking during pregnancy and absence of breastfeeding vary by socio-economic status and are also known to be risk factors for SIDS.^{24,25}

As shown in a previous study,¹⁰ changes in the coding of cause of death are unlikely to have substantially affected SIDS counts.

This study has limitations. We did not have individual-level data on income, education and employment, or other potentially relevant characteristics such as smoking. Neighbourhood income was assigned using postal codes and non-differential misclassification errors in the attribution of neighbourhoods may have attenuated the results, especially in small town and rural areas.²⁶ Neighbourhoods were assigned at time of birth, which may not reflect true res-

idential exposures if mothers had moved either during or after pregnancy. We could not adjust for clustering of births within mothers. Finally, neighbourhood income quintile is only one measure of socio-economic status; we do not know if trends would have been different for other markers of area socio-economic status.

In conclusion, our study shows that despite a decrease in rates of infant mortality and SIDS across all socio-economic strata over time, socio-economic inequalities in those rates have persisted in Canada. This finding highlights the need for effective infant health promotion strategies in vulnerable populations.

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RÉSUMÉ

CONTEXTE : La mortalité infantile a diminué au Canada depuis les années 1990 et 2000 mais nous ignorons si toutes les classes socio-économiques ont bénéficié également de ce progrès.

OBJECTIFS : La présente étude portait sur les différences entre les taux de mortalité néonatale et postnéonatale et de mort subite du nourrisson entre les différents quintiles de revenu des quartiers au Canada de 1991 à 2005.

MÉTHODES : Le fichier couplé des naissances vivantes et des décès infantiles au Canada a été utilisé à l'exclusion des naissances survenues en Ontario, au Yukon, dans les Territoires du Nord-ouest et au Nunavut. Les taux de mortalité néonatale et postnéonatale et de mort subite du nourrisson ont été calculés par quintile de revenu des quartiers et par période (1991-1995, 1996-2000, 2001-2005). Les rapports de risque (RR) ont été calculés par quintile de revenu et période avec ajustement pour la province de résidence, l'âge de la mère, la parité, le sexe du nourrisson et les naissances multiples.

RÉSULTATS : En zone urbaine, pour toute la période étudiée (1991-2005), le quintile de revenu le plus pauvre avait un risque plus élevé de mortalité néonatale (RR ajusté 1,24; IC 95% 1,15-1,34), de mortalité postnéonatale (RR ajusté 1,58; IC 95% 1,41-1,76) et de mort subite du nourrisson (RR ajusté 1,83; IC 95% 1,49-2,26) par rapport au quintile le plus riche. Les taux de mortalité post néonatale et de mort subite du nourrisson ont décliné respectivement de 37 % et de 57 % de 1991-1995 à 2001-2005 alors que le taux de mortalité néonatale n'a pas changé de façon significative. Cette diminution de la mortalité postnéonatale et de la mort subite du nourrisson a été observée dans tous les quintiles de revenu.

CONCLUSION : Malgré une diminution de la mortalité postnéonatale et du syndrome de mort subite du nourrisson dans tous les quintiles de revenu, les inégalités subsistent au Canada. Ce résultat démontre le besoin de stratégies efficaces de promotion de la santé visant spécifiquement les populations vulnérables.

MOTS CLÉS : mort subite du nourrisson; mortalité infantile; statut socio-économique