Université de Montréal

Capacités motrices et retour aux activités physiques après un traumatisme crânio-cérébral léger chez l'enfant

Par
Isabelle Gagnon

École de réadaptation
Faculté de Médecine

Thèse présentée à la Faculté des études supérieures
en vue de l'obtention du grade de Philosophæ Doctor (Ph.D.)
en sciences biomédicales
option réadaptation

Octobre, 2003

Université de Montréal

Direction des bibliothèques

AVIS

L'auteur a autorisé l'Université de Montréal à reproduire et diffuser, en totalité ou en partie, par quelque moyen que ce soit et sur quelque support que ce soit, et exclusivement à des fins non lucratives d'enseignement et de recherche, des copies de ce mémoire ou de cette thèse.

L'auteur et les coauteurs le cas échéant conservent la propriété du droit d'auteur et des droits moraux qui protègent ce document. Ni la thèse ou le mémoire, ni des extraits substantiels de ce document, ne doivent être imprimés ou autrement reproduits sans l'autorisation de l'auteur.

Afin de se conformer à la Loi canadienne sur la protection des renseignements personnels, quelques formulaires secondaires, coordonnées ou signatures intégrées au texte ont pu être enlevés de ce document. Bien que cela ait pu affecter la pagination, il n'y a aucun contenu manquant.

NOTICE

The author of this thesis or dissertation has granted a nonexclusive license allowing Université de Montréal to reproduce and publish the document, in part or in whole, and in any format, solely for noncommercial educational and research purposes.

The author and co-authors if applicable retain copyright ownership and moral rights in this document. Neither the whole thesis or dissertation, nor substantial extracts from it, may be printed or otherwise reproduced without the author's permission.

In compliance with the Canadian Privacy Act some supporting forms, contact information or signatures may have been removed from the document. While this may affect the document page count, it does not represent any loss of content from the document.

Université de Montréal

Faculté des études supérieures

Cette thèse intitulée

Capacités motrices et retour aux activités physiques après un traumatisme crânio-cérébral léger chez l'enfant

Présentée par

Isabelle Gagnon

A été évaluée par un jury composé des personnes suivantes:

Dr. Julie Gosselin
Président rapporteur

Dr. Robert Forget
Directeur de recherche

Dr. Bonnie Swaine
Co-directeur de recherche

Dr. Lise Gauvin
Membre du jury

Dr. Alexander C.H. Geurts
Examinateur externe

Dr. Jean-Marc Lavoie
Représentant du doyen de la FES

RÉSUMÉ

Malgré l'attention grandissante que reçoit le phénomène du traumatisme crânio-cérébral léger (TCL) au sein des champs médicaux et de la réadaptation, une controverse persiste quant aux conséquences laissées par ce type de traumatisme. Chez les enfants, des déficits moteurs et psychosociaux potentiels associés au traumatisme pourraient avoir un impact sur leur participation ultérieure aux activités physiques. L'objectif de ce projet était principalement d'examiner les capacités d'équilibre et de temps de réponse d'un groupe d'enfant ayant subi un TCL au cours d'une période de 12 semaines suivant le traumatisme et de les comparer à celles d'enfants non-blessés pairés pour l'âge, le sexe et le niveau pré-morbide de participation aux activités physiques. Un objectif secondaire était de déterminer si les enfants ayant subi un TCL maintenaient, 12 semaines post-trauma, un niveau d'activités physiques, une perception de leur compétence athlétique et un niveau d'efficacité personnelle comparable à ceux de la période pré-traumatique. Quarante enfants ayant subi un TCL et quarante enfants non-blessés, recrutés parmi les amis des enfants TCL, furent recrutés pour ce projet. Les enfants avec TCL avaient été hospitalisés pour une période d'observation d'une durée de quelques heures, avaient un score moyen à l'échelle de coma de Glasgow de 14,8 et étaient considérés normaux lorsqu'évalués selon une évaluation neurologique habituelle. Les évaluations de l'équilibre et des temps de réponse étaient effectuées 1, 4 et 12 semaines post-TCL tandis que celles mesurant le niveau de participation aux activités physiques, la perception de la compétence athlétique et l'efficacité personnelle étaient faites le jour suivant le trauma et reprises 12 semaines post-TCL. Les évaluations des enfants du groupe contrôle prenaient place à des intervalles équivalents. Les mesures utilisées incluaient des outils d'évaluation divers cherchant à illustrer les performances globales dans les domaines de l'équilibre, des temps de réponse et de l'activité physique. Les résultats principaux révélèrent que les enfants ayant subi un TCL présentaient des performances initiales moindres pour l'équilibre et les temps de réponse que les enfants contrôles. Celles-ci s'amélioraient au cours de la période de 12 semaines mais demeurait diminuées pour quelques unes des mesures. Par ailleurs, à 12 semaines post-trauma, les enfants avec TCL avaient repris un niveau de pratique des activités physiques similaire à celui avant le TCL et maintenu leur perception de la compétence athlétique mais présentaient une diminution de leur efficacité personnelle pour la pratique des activités physiques. Les résultats sont discutés en relation avec les recherches récentes et des perspectives pour les avenues de recherche futures sont suggérées.

Mots clés: traumatisme crânio-cérébral léger, enfants, équilibre, temps de réponse, activités physiques, efficacité personnelle

SUMMARY

Despite the increased attention mild traumatic brain injuries (mTBI) have received in the rehabilitation and medical fields, significant controversy remains as to the extent of the sequelae resulting from such an injury. This is especially the case for children who sustain mTBI, for whom the potential motor and psychosocial disabilities associated with the injury may have an impact on their future participation in physical activities. The main purpose of this project was to examine the balance and response time performances of a group of children who had sustained a mTBI over the first 12 weeks following the injury and to compare the performances to those of a group of non-injured children matched for age, sex and premorbid level of physical activity. A secondary objective was to determine whether children who sustained a mTBI practiced their physical activities 12 weeks after the injury with the same level of self-efficacy and of perceived athletic competence as prior to the injury. Participants were 40 children who had sustained a mTBI and 40 non-injured children, recruited among the friends of the injured children. Children with mTBI had been admitted to hospital for an observation period of several hours to an overnight stay, had a mean GCS of 14.8, and were considered normal on a standard neurological assessment at hospital discharge. Assessments of balance and response time were conducted at 1, 4, and 12 weeks post-mTBI while the administration of the questionnaires concerning the physical activity level, perceived athletic competence and self-efficacy took place on the day after the injury and again 12 weeks later. Assessments were conducted at corresponding time intervals for the control children. Various measurement tools were used too provide a global portrait of the children's performances in the balance, response time and physical activity domains. Results revealed that the mTBI children presented with decreased performances in balance and response time initially. Their performances improved over the following 12-week period but did not return to levels comparable to those of the control group for some measures. As well, at 12 weeks post-trauma, mTBI children had returned to their premorbid level of physical activity participation and had maintained their perceived athletic competence but presented with decreased levels of self-efficacy related to the practice of their physical activities. Results are discussed in relation to the literature and directions for future research are suggested.

Key words: mild traumatic brain injury, children, balance, response time, physical activities, self-efficacy

TABLES DES MATIÈRES

LISTE DES FIGURES

Introduction

Recension des écrits

Méthodologie des travaux

Article 2

Article 3

Article 4

Discussion

LISTE DES TABLEAUX

Recension des écrits

Méthodologie des travaux

Article 1

Article 2

Article 3

Article 4

Article 5

LISTE DES ABBRÉVIATIONS

AC	Athletic Competence subscale of the Self-Perception Profile for Children or Adolescents
ARS	Activity Rating Scale
BOTMP	Bruininks-Oseretsky Test of Motor Proficiency
CQCIDIH	Comité québécois sur la classification internationale des déficiences, incapacités et handicaps
CT	Computerized Tomography
EEG	Électroencéphalographie
IRM	Imagerie par résonance magnétique
IRMf	Imagerie par résonance magnétique fonctionnelle
LAD	Lésions axonales diffuses
PAQ	Physical Acticity Questionnaire
PCTSIB	Pediatric Clinical Test of Sensory Interaction for Balance
PEA	Potentiels évoqués auditifs
PET	Positron Emission Tomography
PEV	Potentiels évoqués visuels
PPH	Processus de production du handicap
PST	Postural Stress Test
SE	Self-Efficacy
SOT	Sensory Organization Test
SPC	Symptômes post-commotionnels
SPECT	Single Photon Emission Tomography
SRM	Spectroscopie par résonance magnétique
TCC	Traumatisme crânio-cérébral
TCL	Traumatisme crânio-cérébral léger
TM	Temps de mouvement
TR	Temps de réaction

REMERCIEMENTS

Ce Travail a été effectué sous la direction de Robert Forget et de Bonnie Swaine à qui je veux exprimer ma reconnaissance et ma profonde gratitude. Sans leur habile direction et leurs commentaires judicieux, il ne m'aurait pas été possible de compléter cette démarche avec succès.

Un grand merci à l'équipe de traumatologie de l'Hôpital de Montréal pour Enfants, plus particulièrement à Debbie Friedman, Allan Ptack et Carlo Galli pour leur collaboration exceptionnelle. Un merci tout spécial à Lisa Grilli et Cathy Rossi pour leur professionnalisme et leur grande disponibilité lors de l'évaluation des enfants.

Je tiens également à remercier toute l'équipe du Centre de recherche de l'Institut de réadaptation de Montréal pour leur grande disponibilité et leur aide précieuse à toutes les étapes de réalisation de ce projet.

Je veux souligner tout particulièrement la grande flexibilité et le soutien de mes collègues de l'hôpital de Montréal pour enfants qui ont su faciliter ma démarche au cours de ces dernières années.

Merci aux enfants et à leurs familles qui ont généreusement accepté de participer aux projets de recherche. Leur contribution à l'avancement des connaissances au sujet du traumatisme crânio-cérébral léger est inestimable.

Merci au Fonds de recherche en santé du Québec pour le soutien financier tout au long de ces études doctorales ainsi qu'aux organismes qui ont subventionné ce projet soit le Réseau provincial de recherche en adaptation-réadaptation, la Fondation Marie Robert pour la recherche sur les traumatisés crâniens, l'Ordre professionnel des physiothérapeutes du Québec et la Fondation canadienne de physiothérapie.

Merci à Claude et à mes parents qui m'ont chaleureusement et généreusement entourée et accompagnée tout au long de ces années.

Finalement je ne peux passer sous silence l'inspiration de Sarah-Jeanne et de Charlotte, les petites lumières de ma vie.

Je dédie cet ouvrage à Claude
pour son amour et son support
ainsi qu'à mes parents
pour leur aide inestimable tout au long de cette démarche

CHAPITRE 1
INTRODUCTION

Les travaux rapportés dans cette thèse ont pour principal objectif l'étude des conséquences motrices d'un traumatisme crânio-cérébral léger (TCL) chez l'enfant et les relations du TCL avec une habitude de vie, soit la participation aux activités physiques. De manière plus particulière, nous avons voulu documenter l'évolution de capacités spécifiques: l'équilibre, les temps de réponse visuo-motrice, l'efficacité personnelle reliées aux activités physiques et la compétence athlétique perçue après un TCL et, étudier le retour aux activités physiques habituelles suite à ce traumatisme.

Deux constats principaux ont motivé l'entreprise de ces travaux et l'étude particulière de ces domaines. D'abord, certains enfants ayant subi un TCL expriment de manière anecdotique des insatisfactions lors de leur retour aux activités physiques habituelles. Ces insatisfactions sont de l'ordre de performances moindres qu'avant le traumatisme ou de sentiments que "quelque chose ne va pas". L'intérêt pour le retour aux activités physiques suite au TCL prend donc assise dans ces évidences anecdotiques. Celui-ci sera abordé du point de vue de la participation aux activités physiques en période post-traumatique mais aussi en examinant des capacités psychosociales liées à la pratique des activités physiques soient l'efficacité personnelle et la compétence athlétique perçue. Dans un deuxième temps, une étude exploratoire auprès de cette clientèle (Gagnon et coll., 1998) révélait la présence d'incapacités d'équilibre et de temps de réponse visuo-motrice lors d'une évaluation unique au cours de la période post-traumatique immédiate (deux semaines post-TCL). Une étude plus particulière de l'évolution des performances des enfants dans ces deux domaines méritait donc aussi une attention certaine.

L'entreprise de tels travaux et l'interprétation des résultats obtenus sont facilitées lorsque situées dans un cadre conceptuel approprié. Le Processus de Production du Handicap (PPH) (Fougeyrollas et coll., 1991, 1998), étudie les interactions entre les individus et leur environnement pour évaluer leur degré de réalisation d'habitudes de vie socialement valorisées et librement choisies compte tenu de l'âge, du sexe et de l'identité socioculturelle d'un individu. Le PPH définit les handicaps (limitations dans les habitudes de vie) en utilisant la définition du comité québécois sur la classification internationale des déficiences, incapacités et handicaps (CQCIDIH) selon laquelle la réalisation ou non d'une habitude de vie résulte de l'interaction entre les facteurs personnels d'une part et les facteurs environnementaux d'autre part. La figure 1 schématise les différentes dimensions de ce modèle conceptuel. Dans le cadre de ces travaux, une situation de handicap quant à la participation aux activités physiques résulterait d'une interaction défavorable entre des facteurs personnels (déficiences du système nerveux causées par un TCL et incapacités motrices ou psychosociales), et des facteurs environnementaux reliés à la pratique des activités physiques.

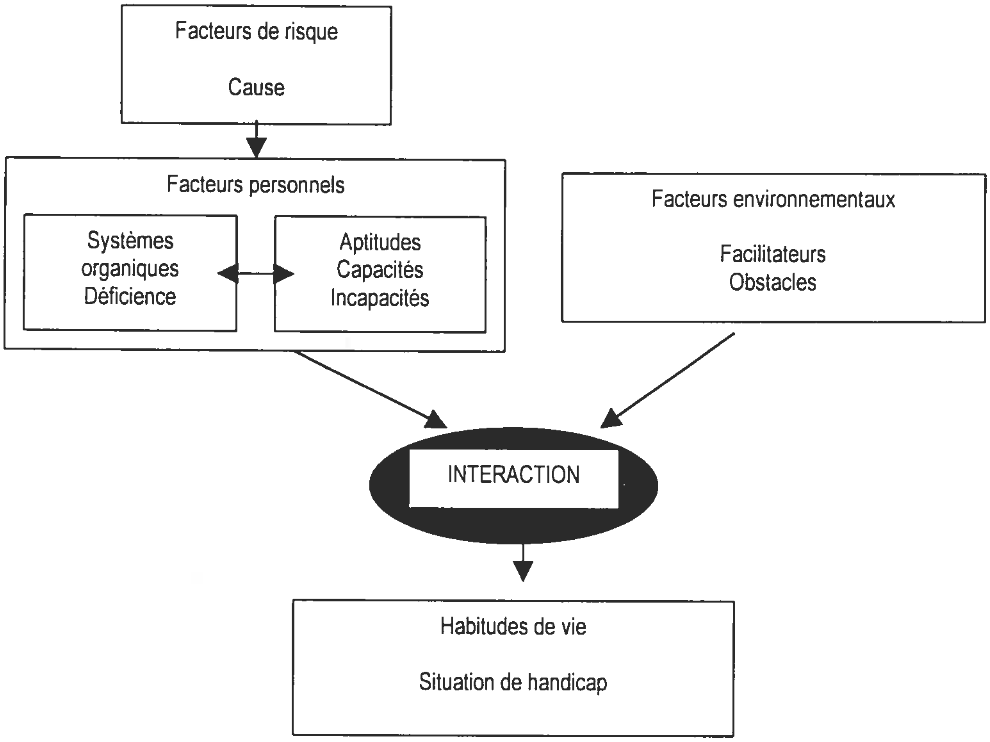


Figure 1: Cadre conceptuel du Processus de Production du Handicap.

La présente thèse est divisée en quatre grandes parties. La première s'intéressera à la recension des écrits structurée selon le modèle présenté ci-haut. Elle portera sur le TCL pédiatrique, sur ses conséquences au niveau des systèmes organiques et des capacités. Il y aura une emphase sur les capacités motrices d'équilibre et de temps de réponse et sur les capacités psychosociales d'efficacité personnelle et de compétence athlétique perçue. Le retour aux activités physiques après un TCL chez l'enfant sera ensuite revu en clarifiant les facteurs pouvant influencer la participation et la performance à ce type d'activités.

La deuxième partie rapportera la méthodologie utilisée pour les études expérimentales et la troisième présentera les résultats expérimentaux sous forme d'articles scientifiques publiés ou soumis pour publication. Un premier article (article 1), ayant servi d'assise pour les travaux, consiste en une histoire de cas unique documentant l'évolution des capacités d'équilibre d'une enfant avant et après avoir subi un TCL dans le cadre d'une activité sportive récréative. La documentation des capacités pré-traumatiques chez des individus issus de la population générale plutôt que de groupes d'athlètes d'élite est rare, voire inexistante dans les écrits. C'est ce qui définit le caractère novateur de cette histoire de cas et justifie son inclusion au sein de la thèse.

Les trois articles qui suivent (articles 2, 3 et 4) forment le cœur de la thèse et sont composés des résultats de l'étude principale de ces travaux. Le premier de cette série (article 2) traite des résultats concernant l'équilibre des enfants après un TCL. Viennent ensuite les résultats concernant les temps de réponse au cours de la période de suivi (article 3). Nous terminons cette section par l'article se penchant sur les activités physiques (article 4). Nous avons aussi exploré les liens existant entre les incapacités identifiées dans les deux premiers articles (2 et 3) et leur impact sur le retour aux activités physiques chez le groupe d'enfants étudiés (article 4). Ces résultats ne sont pas partie intégrante des articles scientifiques mais seront repris au sein de la discussion plus générale dans le dernier chapitre de cette thèse.

Enfin, un dernier article (article 5) rapporte les résultats d'une étude connexe chez un échantillon d'enfants sains, cherchant à explorer les liens entre deux outils d'évaluation de l'interaction sensorielle au service du maintien de l'équilibre en station debout. Ces deux outils sont utilisés en milieu clinique et l'un d'entre eux fait partie des mesures d'équilibre utilisées pour l'étude principale de cette thèse. L'hypothèse que ces deux outils sont équivalents a été évaluée et les résultats, présentant peu de liens avec ceux traitant des déficits post-TCL, ne seront pas repris dans la discussion générale de la thèse.

Finalement, la quatrième partie consistera en une discussion générale de l'impact des résultats obtenus au cours de ces travaux. Celle-ci est articulée autour de trois grands thèmes soient: 1) les constats généraux pouvant être dégagés de nos résultats, 2) les liens significatifs entre les performances des enfants dans les divers domaines étudiés et finalement 3) les impacts réels de nos résultats sur la vie des enfants et les perspectives futures découlant de ceux-ci.

CHAPITRE 2

RECENSION DES ÉCRITS

Le cadre conceptuel du PPH structurera cette première partie de la thèse. La recension des écrits sera articulée, selon le modèle, en quatre grandes sections à savoir; 1) le traumatisme crânio-cérébral léger (TCL), 2) les systèmes organiques lésés suite au TCL, 3) les capacités ou incapacités rapportées suite au TCL avec emphase sur les incapacités motrices et psychosociales reliées à la pratique des activités physiques, et 4) l'habitude de vie d'intérêt pour ces travaux: le retour aux activités physiques après un TCL. La figure 2 situe les domaines à l'étude dans le cadre conceptuel du PPH.

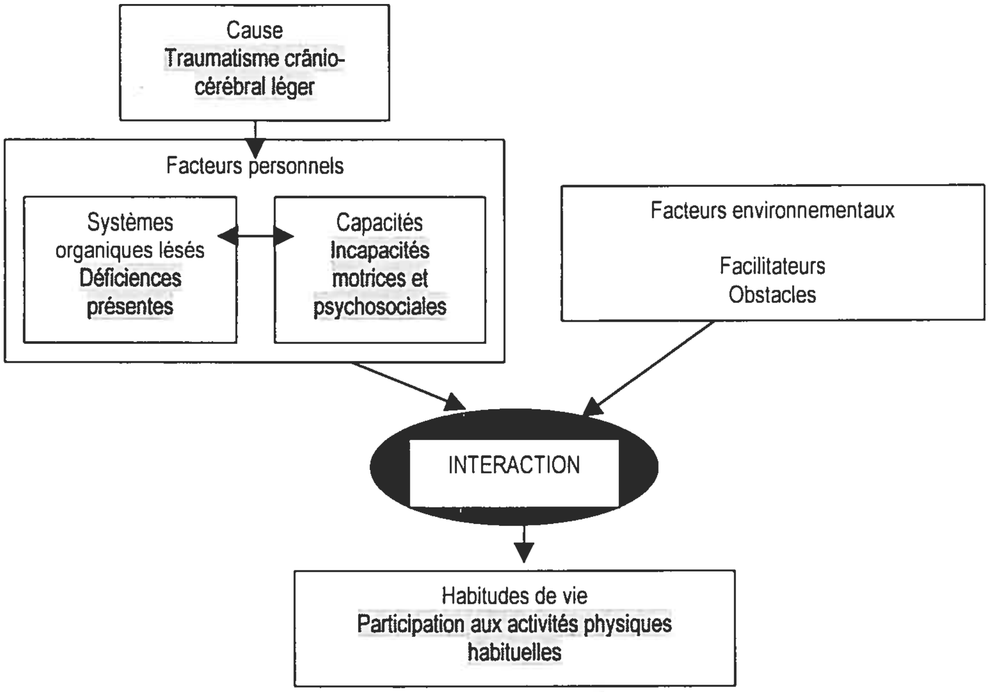


Figure 2: Cadre conceptuel du PPH adapté aux domaines d'intérêts de nos travaux. Les items surlignés représentent les domaines à l'étude et revus dans la recension des écrits

2.1 Le traumatisme crânio-cérébral léger: causes, incidence et sévérité

On entend par traumatisme crânio-cérébral (TCC) une perturbation physiologique du fonctionnement cérébral provoquée par un impact impliquant soit un contact à la tête, soit un changement abrupt des forces d'accélération-décélération, associé à une altération de la conscience ou à de l'amnésie post-traumatique ou à des signes et symptômes reconnus (ACRM, 1993). Les causes des TCC varient en relation avec l'âge mais sont, chez l'enfant, surtout liées aux chutes, aux accidents de la route, et aux agressions diverses incluant les blessures par balles (Levin et coll., 1992a). Des questions demeurent quant à l'incidence réelle des TCC. Ceci est en partie dû à une certaine confusion face à la définition et à un recensement incomplet souvent limité aux cas nécessitant une hospitalisation (Kraus et coll., 1994). Les écrits rapportent des taux allant de 91/100 000 à 322/100 000 (Kraus et coll., 1984; Vasquez-Barquero et coll., 1992; Charron, 1992; Hillier et coll., 1997) pour la population générale. Ces taux semblent être sensiblement les mêmes pour la population pédiatrique (Kraus et coll., 1987; 1990).

Il est utile de séparer les TCC en degrés de sévérité à l'aide de systèmes de classification regroupant les sujets par signes cliniques et radiologiques. On distingue alors trois degrés de sévérité: sévère, modéré et léger. Le TCC sévère est caractérisé par la présence de lésions significatives à l'encéphale, par un score à l'échelle de Glasgow entre 3 et 8 et par une période de perte de conscience d'une durée de plus de 6 heures tandis que le TCC modéré est caractérisé par des lésions variables mais surtout par un score à l'échelle de Glasgow entre 9 et 12 et par une période de perte de conscience comprise entre 30 minutes et 6 heures (Stein, 1996). Les critères d'appartenance au TCC léger (TCL) sont probablement les plus variables de toutes les catégories mais, en général, on reconnaît que la présence d'au moins un des critères suivants mène à la classification de TCL: un score à l'échelle de coma de Glasgow entre 13 et 15, une perte de conscience ne dépassant pas une durée de 30 minutes, une amnésie post-traumatique de moins de 24 heures et une absence de signes neurologiques anormaux (ACRM, 1993).

Reconnu de nos jours comme une entité distincte, le TCL fut longtemps l'objet d'une controverse quant à son existence et à l'étendue des déficits qui y sont associés (Strauss & Savitsky, 1934; Miller, 1961; Miller, 1996). Une confusion demeure quant aux termes à utiliser pour le nommer (léger, mineur, très léger, commotion) mais il est généralement reconnu qu'il représente entre 75 et 80% de tous les TCC chez l'adulte et l'enfant (Kraus, et coll., 1994 Miller & Jones, 1990). Pour certains, surtout au sein de la communauté sportive et athlétique, la catégorie "TCL" demeure trop large et une division en sous-groupes est utilisée (Alexander, 1995). On reclasse donc les TCL en trois sous-groupes ou grades en se basant sur des critères variant légèrement selon les auteurs mais tous liés à la présence et durée de la perte de conscience (Cantu,1986; CMS,1991; AAN, 1997). Lorsqu'utilisés au sein de ces travaux et présentés dans les articles scientifiques, les grades de TCL se référeront à la classification élaborée par l'AAN (1997) présentée au tableau 1.

TABLEAU 1: Classification du traumatisme crânio-cérebral léger selon l'American Academy of Neurology.

Critères	Perte de conscience	Présence de symptômes
Grade 1	Aucune	Moins de 15 minutes
Grade 2	Aucune	Plus de 15 minutes
Grade 3	Présence de perte de conscience peu importe la durée	

2.2 Les systèmes organiques lésés suite au TCL

Du point de vue neuropathologique, les dommages les plus caractéristiques du TCL sans fracture, hémorragie ou contusion spécifique sont les lésions axonales diffuses (LAD). Celles-ci résultent de la torsion générée au sein de l'encéphale par des mécanismes d'accélération-décélération soudaines (Oppenheimer, 1968; Adams et coll., 1982; Polivshock et coll., 1986; Mittl et coll., 1994; Graham, 1996). Ces forces de torsions endommagent les structures fragiles qui voyagent dans l'axe long du cerveau, principalement des vaisseaux sanguins et des axones (Alexander, 1995). Lorsque des cellules nerveuses sont irréversiblement endommagées par les LAD (i.e. mort cellulaire primaire) des processus sont enclenchés qui mènent à des pertes neuronales supplémentaires par nécrose cellulaire antérograde ou rétrograde, par dégénération transynaptique ou transneuronale (i.e. mort cellulaire secondaire). Le rôle spécifique des neurotransmetteurs demeure incertain comme cause de perte et de mort cellulaire. Les dommages vasculaires quant à eux seraient responsables de la destruction de petits vaisseaux menant à des hémorragies focales ou de l'œdème localisé. La distribution primaire de ces dommages semble se situer au sein de la matière blanche parasagittale profonde s'étendant du cortex au tronc cérébral.

Ces dommages structurels généraux furent mis en évidence lors *d'études expérimentales* à l'aide de tests neurodiagnostiques d'imagerie médicale (e.g. radiographie crânienne, computerized tomography (CT), résonance magnétique (IRM et SRM)), d'imagerie fonctionnelle (e.g. résonance magnétique fonctionnelle (IMRf), single photon emission tomography (SPECT), positron emission tomography (PET)), ou d'enregistrement de l'activité électrique du système nerveux central soit spontanée (électroencéphalographie (EEG)) ou évoquée (potentiels évoqués visuels (PEV), auditifs (PEA)) (Sullivan et coll., 1994). Il existe cependant une variabilité considérable dans l'utilisation clinique de ces tests chez la population de personnes ayant subi un TCL (Stiell et coll., 1997).

La radiographie crânienne a longtemps été, et demeure probablement, l'outil diagnostique le plus disponible et le plus utilisé avec la clientèle se présentant à l'urgence avec une histoire de TCL (Burkinshaw, 1960; Vollmer et coll., 1991). Très utile dans la classification de fractures du crâne, elle demeure peu utile pour l'identification de lésions corticales (Servadei et coll., 1995; Vollmer et coll., 1991; Murshid, 1994;). Le CT scan de routine reçoit la cote dans plusieurs centres. Ce test arrive en effet à identifier les hématomes sous-duraux et certaines lésions axonales diffuses, mais surtout à séparer les quelques candidats qui requerront une chirurgie corrective de ceux qui peuvent recevoir un congé sans risque de complications (Dietrich et coll., 1993; Jeret et coll., 1993; Davis et coll., 1995; Miller, 1996; Ingebritsen & Romer, 1996). Cependant il reste peu sensible aux lésions à la matière blanche qui pourraient aider à identifier les TCL risquant de développer des incapacités tels les symptômes post-commotionnels, par exemple (Orrison et coll.,1994). L'IRM est plus sensible aux lésions post-traumatiques que le CT, surtout pour la détection de contusions non-hémorragiques et de lésions axonales diffuses (Mittl et coll., 1994; Hofman et coll, 2001). Les indices quant aux altérations fonctionnelles du métabolisme de l'encéphale suite au TCL sont fournis par les études de SPECT et de PET par leur capacité à identifier les troubles de perfusion cérébrale et de métabolisme dans des régions endommagées, et ce, même pour des TCC plus légers (Roper et coll., 1991; Ichise et coll., 1994; Jacobs et coll., 1996; Kant et coll., 1997; Ashwal et coll., 2000; Garnett et coll., 2000). Les études d'EEG et de potentiels évoqués peuvent aussi fournir des indices quant à l'état encéphalique mais s'avère d'une utilité discutable chez la population de TCL pour identifier les individus qui développeront des incapacités significatives suite au traumatisme (Ruijs et coll., 1994; Wallace et coll., 2001).

Aucun consensus international n'existe donc concernant les critères d'administration de ces tests coûteux et non disponibles dans tous les centres recevant la clientèle des TCL. D'autant plus que les liens entre les anomalies cérébrales retrouvées chez certains patients, et les performances neuro-cognitives ou neuropsychologiques après le TCL, demeurent difficiles à établir avec certitude (Overgoard et coll., 1981; Levin et coll., 1987; 1992b; Sullivan et coll., 1994; Multi-Society Task Force on PVS, 1994; Marion, 1996; Umile et coll., 1998; Hofman et coll., 2001). Vu les difficultés relevées ci-haut, un guide de bonne pratique clinique publié récemment au sujet de la prise en charge des enfants suite à un TCL suggère l'utilisation initiale de tests neuro-diagnostiques, autres que les rayons-X pour éliminer la présence de fractures, seulement lors de TCL impliquant une perte de conscience supérieure à une minute, ou en cas de détérioration ultérieure de l'état de l'enfant. Pour les cas les plus légers, une surveillance adéquate de l'évolution des symptômes est recommandée et considérée comme suffisante (AAP, 1999).

2.3 Capacités affectées après un TCL

Au cours des 50 dernières années, la grande majorité des écrits sur les TCC se sont concentrés sur la population adulte et sur les cas les plus sévères chez qui les conséquences sont sans équivoques. Ce n'est qu'au cours de la dernière décennie que l'intérêt des chercheurs s'est porté sur les cas les plus légers, car bien que considérés comme mineurs, les problèmes reliés à certains TCL méritent une attention évidente (Boll & Barth, 1983). Par ailleurs, les TCC chez les enfants étant distincts tant par leurs causes que par leurs conséquences potentielles sur un système nerveux en développement, il est essentiel de reconnaître que les études traitant de populations adultes peuvent mener à des conclusions incomplètes à propos de la population pédiatrique.

Kraus et coll. (1987) et Levin et coll. (1988) décrivent des différences étiologiques et pathophysiologiques concernant les TCC pédiatriques lorsque comparés à ceux subis par les adultes. Ceux-ci sont plus souvent le résultat de chutes lors d'activités (basse vélocité) contrairement aux accidents de la route (plus haute vélocité) qui sont la cause la plus fréquente chez les adolescents plus vieux et les adultes et mènent à des forces de torsions (responsables des LAD) de plus grande envergure. L'état de développement inachevé des systèmes organiques des enfants les rendent potentiellement plus vulnérables aux effets du TCC pendant l'enfance et le début de l'adolescence. Cependant, la grande variabilité dans le rythme de maturation de tous les domaines chez les enfants rend difficile d'attribuer un ralentissement des fonctions ou de la maturation à des variations naturelles ou au TCC lui-même (Fletcher et coll., 1987; Levin et coll., 1988; Segalowitz & Brown, 1991). De plus, même au sein des études faites chez les enfants, comme chez celles traitant d'individus adultes, des problèmes méthodologiques existent tels l'hétérogénéité de la population en termes de sévérité, d'âge, l'absence de groupe de référence, ou de mesures de déficits non spécifiques (Chaplin et coll., 1993). Il est donc clair que pour enfin arriver à établir la présence ou l'absence de déficits chez les enfants et plus particulièrement après un TCL, des critères précis doivent être établis quant à la définition de la sévérité du traumatisme, aux domaines de capacités évaluées, à la période de suivi, au choix judicieux d'un groupe de comparaison et au contrôle de données pré-traumatiques.

Suite aux études menées chez les clientèles adulte et pédiatrique, quelques constats généraux peuvent être relevés concernant les incapacités présentes post-TCL. En général, la période de récupération des incapacités et des symptômes post-commotionnels semble s'échelonner en grande partie au cours des trois premiers mois (Alves et coll., 1986; Levin et coll., 1987a; Evans, 1992) mais continue jusqu'à un an chez certains patients (Middleboe et coll., 1992). Dans ces études, lorsque des troubles sont détectés chez des groupes de sujets TCL, ils sont principalement d'ordre cognitif tels des problèmes de mémoire ou de traitement de l'information (Levin et coll., 1987a), et d'attention (Parasuraman et coll., 1991; Cicerone, 1997). Peu de problèmes moteurs sont identifiés bien que récemment, des problèmes de performance avec contrainte de temps pour des tâches motrices simples (Haaland et coll., 1994) ou encore des problèmes d'équilibre aient été identifiés dans les premiers jours post-trauma (Guskiewicz et coll., 1997; Gagnon et coll., 1998). Ces troubles de l'équilibre pourraient perdurer pendant plusieurs mois (Geurts, 1996), même en l'absence de déficits neuropsychologiques (Geurts et coll., 1999). Les sections suivantes discuteront de ces incapacités diverses en se concentrant sur la clientèle pédiatrique. Cependant, comme les écrits provenant d'études menées avec des populations adultes peuvent parfois éclairer la discussion, ils seront discutés au besoin pour clarifier ou illustrer certains points lorsque leurs résultats sont particulièrement novateurs. Les prochaines sections seront donc consacrées à la revue des incapacités recensées suite à un TCL en commençant par les symptômes considérés comme caractéristique du TCL, les symptômes post-commotionnels. Suivront les incapacités reliées aux domaines cognitif, comportemental et moteur avec emphase sur l'équilibre et les temps de réponse pour cette dernière section.

2.3.1 Les symptômes post-commotionnels

Les symptômes post-commotionnels (SPC), parfois regroupés en *syndrome post-commotionnel*, représentent la complication la plus reconnue du TCL. Comme aucune étude rapportant de manière standardisée la présence et la sévérité de SPC chez enfants ne put être recensée, la section rapportera surtout des résultats provenant de travaux effectués auprès d'adultes. Depuis son introduction dans la littérature, le syndrome est au centre d'une controverse quant à l'origine, organique ou psychologique, des symptômes qui le composent. Strauss et Savitsky (1934) introduisent le terme "post-concussion syndrome" dans un article où ils reconnaissent la présence, suite à un traumatisme à la tête pouvant être considéré comme mineur, de symptômes pouvant nuire au fonctionnement de l'individu. En général, de nos jours, on convient de son existence malgré une controverse persistante quant à la durée et la portée des symptômes (Alves et coll., 1993). On reconnaît donc la présence du SPC dans près de 50% des cas de TCL (Mandel, 1989; Szymanski & Linn, 1992) dans les semaines ou même les mois qui suivent le traumatisme initial, même chez les patients n'ayant eu aucune perte de conscience et considérés comme des cas très légers. Ces symptômes peuvent subsister de manière chronique six mois après le traumatisme dans 15-29% des cas (Hofman et coll., 2001) et même jusqu'à un an chez certains (Evans, 1996). Une liste des symptômes est présentée au tableau 2, mais les symptômes les plus fréquemment rapportés peuvent être classés en symptômes d'ordre physique (maux de tête, étourdissements, fatigue), en difficultés cognitives (concentration, mémoire) et en symptômes d'ordre plus comportemental (irritabilité, colère, dépression) (Kay et coll., 1992; Bernstein , 1999).

TABLEAU 2: Symptômes post-commotionnels les plus fréquemment rapportés

Catégories	Symptômes
Physique	Maux de tête
	Nausées
	Sensations d'étourdissements
	Sensibilité à la lumière
	Sensibilité aux bruit, troubles auditifs
	Fatigue
	Vision trouble
	Vision double
Cognitif	Troubles de la mémoire
	Manque de concentration
	Ralentissement de la pensée
Changements comportementaux, de la personnalité	Sensation de tristesse, état dépressif
	Irritabilité
	Sensation de frustration ou d'impatience
	Trouble du sommeil
	Agitation

Il existe une disparité et même une controverse concernant la pathogénèse du SPC au sein des écrits (Bohnen & Jolles, 1992). En effet, plusieurs symptômes communs du SPC sont aussi retrouvés chez des individus présentant des conditions psychologiques ou psychiatriques. D'un côté, des facteurs psychologiques et motivationnels (e.g. litigation) sont cités comme causes du SPC persistant (Mackay, 1960, Miller, 1961; Lishman, 1988). Cependant, plusieurs auteurs ont démontré une absence de résolution du SPC même après la fin de procédures légales visant une compensation financière suite au TCL (Merskey & Woodforde, 1972; Guthkelch, 1980; Alves et coll., 1986; Lemmon et coll., 1995). De l'autre côté, les hypothèses de l'origine organique du SPC sont présentées par d'autres groupes. Il suffit de dire ici qu'aucune étude n'a pu démontrer des relations claires entre les SPC et les changements organiques. L'hypothèse la plus probable quant à la pathogénèse du SPC consiste probablement en une approche tenant compte de l'interaction entre des facteurs psychogènes et organiques (Rutherford et coll., 1979; Lishman, 1988; Alexander, 1992; Bohnen et coll., 1993). L'identification de variables personnelles ou émotionnelles pouvant prédire l'apparition des symptômes et leur durée chez certains individus génère un intérêt certain. En effet, l'identification des individus "à risque" faciliterait le développement de programmes de prévention et d'intervention consistant généralement en interventions psychosociales (éducation, monitoring des symptômes, counselling et réassurance quant à la résolution des symptômes) (King et coll., 1997; 1999). Des essais randomisés de ces interventions démontrent d'ailleurs leur efficacité (King et coll., 1997; Paniak et coll., 1998; Wade et coll., 1998).

2.3.2 Capacités cognitives

Dans une revue générale s'intéressant aux conséquences cognitives du TCL chez l'enfant, souvent révélées par des épreuves neuropsychologiques, Satz et coll. (1997) recensèrent 40 études ayant pris place au cours d'une période de 25 ans et dont près de la moitié dataient des cinq années précédant la publication. Parmi les études recensées, 13 identifiaient des déficits d'ordre cognitif ou académique associés au TCL, 18 concluaient à l'absence de problème suite à un tel traumatisme, tandis que neuf ne permettaient pas d'arrêter une conclusion définitive. Ainsi, parmi les travaux relevant la présence de déficits post-trauma, six études rapportant des difficultés au niveau académique sont identifiées mais qualifiées de faibles du point de vue méthodologique. Les problèmes rapportés sont d'ordre de l'absentéisme excessif, de manque de progrès académiques et de troubles comportementaux lors de situations d'apprentissage. Du point de vue neuropsychologique, en utilisant des mesures diverses de capacités cognitives (tests neuropsychologiques standardisés telles le Weschler ou la batterie Halstead-Reitan), de langage et de traitement de l'information, huit études démontrent la présence de troubles au cours de la période de suivi post-traumatique, cette période pouvant s'étendre de 1 à 18 mois selon l'étude. Les épreuves les plus sensibles à l'effet du TCL semblent être celles reliées à des tâches motrices avec composante de performance rapide ou de traitement de l'information (Gulbrandsen, 1984; Mattson et coll., 1990; Knights et coll., 1991; Butterbaugh et coll., 1993), celles avec une composante de mémoire non-verbale (Ewing-Cobbs et coll., 1990) et celles se penchant sur les aptitudes visuo-spatiales des enfants (Levin & Eisenberg, 1979). Malgré ces résultats, plusieurs études recensées dans le cadre de cette revue utilisant les mêmes épreuves neuropsychologiques que les précédentes mais présentant une meilleure méthodologie ne témoignent, quant à elles, d'aucun effet suite au TCL. Pour cette raison, Satz et coll. concluent à l'absence d'évidences probantes quant à la présence de déficits suite à un TCL chez l'enfant.

D'autres études d'intérêt doivent être rapportées ici pour illustrer les effets du TCL et les patrons de récupération présents suite au trauma. Levin et coll. (1987) relevèrent des déficits de l'attention, de la mémoire et de vitesse de traitement de l'information dans les jours suivant le TCL, déficits résolus lors d'une réévaluation trois mois post-trauma. Wrightson et ses collègues (1995) soulignent que les TCL peuvent laisser des changements subtils mais significatifs au niveau de facultés cognitives pouvant potentiellement affecter la performance scolaire des enfants d'âge préscolaire ayant subi un TCL ne nécessitant pas d'hospitalisation (très léger). À l'aide de tests cognitifs et du comportement administrés pendant le premier mois, à 6 et 12 mois post-trauma et finalement à l'âge de 6,5 ans, ces enfants sont comparés à des enfants ayant subi des blessures ailleurs au corps. À 6 et 12 mois post-TCL, la performance à un des tests cognitifs concernant la perception visuelle était diminuée et le risque d'avoir contracté un second TCL était légèrement augmenté. De plus, à 6,5 ans, ces enfants avaient plus de chance d'avoir requis de l'aide dans l'apprentissage de la lecture, démontrant des effets potentiels sur l'apprentissage qui semblent perdurer. Finalement, Nolin (2000) identifie des problèmes de flexibilité mentale et de vitesse de traitement de l'information à l'aide de tests d'attention chez un groupe de 15 enfants âgés de 8-15 ans testés entre trois mois et trois ans post-TCL.

La présence de troubles cognitifs suite au TCL ne fait cependant toujours pas l'unanimité au sein de la communauté scientifique. En utilisant des épreuves neuropsychologiques standardisées (incluant des tâches motrices effectuées sous la contrainte du temps) des évaluations d'ordre académique de même que des questionnaires aux parents et éducateurs sondant le fonctionnement social des enfants, Fay et coll. (1993) démontrèrent qu'à six semaines et un an post-trauma les enfants se situaient dans les limites normales au niveau de toutes les mesures d'intérêt. De même, Bijur et coll. (1990) arrivent aussi à la conclusion qu'un TCL subi par des enfants d'âge scolaire ne mène à aucun effet négatif sur le comportement et le fonctionnement cognitif lorsqu'évalués un et cinq ans post-trauma. Le contrôle de variables pré-traumatiques telles l'intelligence, l'agressivité etc. était optimal dans cette étude, le devis étant longitudinal et la cohorte, très nombreuse (n=13 000). Finalement, Ponsford et coll. (1999, 2001) rapportent qu'à une semaine post-TCL, un groupe d'enfants présentent plus de symptômes post-commotionnels qu'un groupe d'enfants contrôles mais aucune différence au point de vue des mesures neuropsychologiques s'intéressant à l'attention, à la mémoire et à la vitesse de traitement de l'information.

Vu le manque de constance des conclusions des études recensées ci-haut, il demeure difficile de statuer définitivement quant à la présence de problèmes cognitifs ou académiques suite au TCL. Des déficits au niveau de l'attention globale, du traitement de l'information, de la mémoire et de la concentration semblent être ceux les plus fréquemment rapportés chez les enfants, bien que l'impact de ces incapacités soit peu clair.

2.3.3 Capacités liées au comportement et à la personnalité

La question des changements au niveau du comportement et de la personnalité suite au TCL soulève aussi beaucoup de controverse au sein des écrits. Des troubles au niveau de ces domaines sont identifiés et rapportés chez les adultes (Brooks & McKinlay, 1983). Cependant, vu la parcimonie des études bien contrôlées menées sur le sujet avec les enfants, les conclusions sont tout aussi difficiles à interpréter que lorsqu'on traite de la question des troubles cognitifs.

Certains des symptômes considérés comme faisant partie intégrante du syndrome post-commotionnel ont trait à des changements au niveau du comportement tels l'irritabilité, la colère, la dépression et ceux-ci sont bien documentés suite au TCL, même chez l'enfant (Ponsford et coll., 1999). Quelques études d'intérêt, approchant la question du comportement et de la personnalité spécifiquement, sont cependant recensées et abordées ici. D'abord Black et coll. (1969) suivirent un groupe d'enfants post-TCC (prépondérance de TCL) de manière prospective (sur cinq ans) et rapportèrent des troubles variés post-trauma incluant la colère, l'irritabilité, les troubles du sommeil, le manque du discipline et l'hyperkinésie. Cette étude n'incluait aucun groupe de comparaison mais les auteurs soulignaient que bien que certains de ces troubles étaient apparus pour la première fois suite au TCL, beaucoup existaient aussi chez les enfants de la population générale. Quelques études entreprises dans les années 1980, étudiant les changements du comportement par entrevue avec les parents apportent peu d'éclaircissements à cette question par leurs conclusions contradictoires et par leur méthodologie (Brown et coll., 1981). Plus récemment, les auteurs tendent à utiliser des échelles standardisées pour l'évaluation du comportement et de la personnalité et apportent un peu de lumière sur la question. Par exemple, Asarnow et coll. (1991) rapportent des taux plus élevés de troubles du comportement mais non de l'anxiété suite au TCL chez 10 enfants évalués un an post-trauma. L'absence d'un groupe contrôle et la petite taille de l'échantillon limite cependant l'interprétation de ces résultats. Par ailleurs, Fletcher et coll. (1990) ne démontrèrent aucun changement de performance suite à un TCL (en contraste à un TCC sévère ou modéré) lorsque les enfants étaient évalués à l'aide d'échelles reconnues du comportement et de l'anxiété au cours de la première année post-trauma. De même, Bijur et coll. (1990) et Fay et coll. (1993), dans le cadre d'études prospectives décrites à la section sur les capacités cognitives, arrivent aussi à la conclusion qu'un TCL subi par des enfants d'âge scolaire ne mène à aucun effet négatif sur le comportement un an post-trauma, lorsque celui-ci est évalué à l'aide d'échelles standardisées et comparé à un groupe d'enfants contrôles.

2.3.4 Capacités motrices

En général, les capacités motrices sont largement négligées dans les études d'adultes ayant subi des TCL sauf dans le cadre de tests neuropsychologiques contenant certains items moteurs ou de tests de temps de réaction. Cette négligence est la conséquence d'observations cliniques qui assument en général que comparativement aux capacités cognitives, les habiletés motrices sont moins sensibles aux dommages du TCL et que si elles sont affectées, elles récupèrent plus rapidement ou laissent des séquelles beaucoup moins importantes que les premières (Haaland et coll., 1994). Chez les enfants ayant subi un TCL, les écrits sont encore plus rares et les conclusions concernant les capacités motrices de ces enfants sont souvent arrêtées sur la base des tests neuropsychologiques cités plus hauts. Les prochaines sections seront d'abord consacrées à la discussion des travaux ayant étudié les capacités motrices générales des enfants post-TCL. Ensuite, l'emphase sera mise sur les deux capacités motrices centrales à ces travaux: les temps de réponse et l'équilibre.

2.3.4.1 Capacités motrices générales

Évaluant la performance motrice de leur cohorte d'enfants ayant subi un TCL à l'aide de questionnaires aux parents, Fay et coll. (1993) concluent à l'absence de déficit d'ordre moteur suite au TCL. Le choix de ce type d'évaluation est justifiable dans le cadre d'études multivariées s'intéressant à plusieurs domaines à la fois, mais la nature globale du test de performance motrice utilisé ici peut limiter les conclusions au niveau de ce domaine. Klonoff et coll. (1993), quant à lui, publia les résultats d'un suivi à très long terme d'un groupe d'enfants ayant subi un TCC de tout type de sévérité, dont environ 85% étaient légers. Après recensement des plaintes subjectives éprouvées par les sujets, les résultats démontrent que 23 ans après le traumatisme, 37,7% des membres de l'échantillon se plaignaient de problèmes physiques tels le manque de coordination, la présence d'étourdissements ou de douleurs musculosquelettiques diverses. L'impossibilité d'identifier quels symptômes provenaient spécifiquement des sujets ayant subi un TCL et l'absence de conclusion quant à l'impact de ces problèmes sur la vie quotidienne des enfants maintenant devenus adultes limite la portée de ces résultats. Ces mêmes enfants avaient été évalués pendant les cinq premières années post-trauma. Au cours de cette période, leur performance à des tests neuropsychologiques, incluant quelques aspects moteurs, ne permettait pas de conclure à la présence de déficits (Klonoff et coll., 1977). Finalement, Ewing-Cobbs et coll. (1989) évalua un groupe d'enfants d'âge préscolaire ayant subi soit un TCC sévère ou un TCL et trouva que dans ce dernier groupe, la performance des enfants aux épreuves cognitives, motrices et de langage immédiatement post-trauma était réduite comparée à leur propre performance huit mois plus tard. Ici encore, l'absence d'un groupe d'enfants contrôles limite l'interprétation des résultats.

La seule étude connue, où des enfants ayant subi un TCL furent évalués de manière standardisée spécifiquement au niveau du domaine moteur est celle de notre groupe (Gagnon et coll., 1998). Dans cette étude, vingt-huit enfants furent évalués à l'aide d'un test de performance motrice, le Bruininks-Oseretsky test of Motor Proficiency (BOTMP) et comparés aux normes publiées pour ce test. Des déficits au sous-tests d'équilibre et de temps de réponse du BOTMP furent relevés chez plus de 40% des enfants deux semaines post-trauma. Comme dans plusieurs études citées précédemment, l'absence d'un groupe d'enfants contrôles limite les interprétations et généralisations pouvant être tirées de cette étude.

En se basant sur les écrits cités précédemment, nous avons choisi de nous pencher plus spécifiquement sur les temps de réponse et sur l'équilibre, deux capacités ayant été identifiées comme potentiellement problématiques chez la population pédiatrique ayant subi un TCL et ayant un effet probable sur la participation aux activités physiques. La prochaine section s'attardera à la question du contrôle des temps de réponse et de l'équilibre de même qu'à une analyse plus poussée de l'impact d'un TCL sur ces deux capacités.

2.3.4.2 Les temps de réponse

2.3.4.2.1 Définition et contrôle des temps de réponse

Le temps de réponse peut-être défini, de manière large, comme le temps requis par un individu pour identifier, réagir et répondre de façon appropriée à un stimulus spécifique. Il représente donc le temps total entre la présentation d'un stimulus et la réponse complétée. Plusieurs systèmes sont impliqués dans la production de ce que l'on mesure comme un temps de réponse, notamment la capacité attentionnelle qui favorisera la perception du stimulus, les systèmes sensoriels qui localiseront, transmettront et interpréteront l'information provenant du stimulus, les régions cognitives qui traiteront cette information et sélectionneront la réponse voulue en activant les commandes motrices appropriées et le système neuro-musculo-squelettique qui sera en charge de la réponse motrice. Lorsque le stimulus attendu demande une réponse motrice déterminée à l'avance, donc sans choix, l'étape de sélection de la réponse n'existe pas et le temps de réponse est qualifié de <u>simple</u>. Cependant, lorsque des choix existent quant à l'activité motrice à exécuter en réponse au stimulus, le temps de réponse est appelé <u>au choix</u> et perçu comme une fenêtre ouverte sur le traitement d'information.

Le temps de réponse visuo-moteur se divise en deux entités distinctes; le temps de réaction (TR) et le temps de mouvement (TM). Le TR correspond à l'intervalle entre la présentation du stimulus et l'initiation du mouvement. Quant au TM, il débute quand le TR prend fin et correspond à l'intervalle entre le début et la fin du mouvement. Selon un cadre conceptuel de traitement de l'information, tiré du "additive factor model" (Sternberg, 1969, Van Zomeren & Brouwer, 1994) le TR comprend quatre stades: 1) extraction des composantes du stimulus, 2) identification du stimulus, 3) sélection de la réponse, et 4) ajustement moteur. Le TM est quant à lui une cinquième étape, indépendante, dans ce modèle, et est appelé "exécution de la réponse". Les étapes d'identification du stimulus telles l'abstraction, l'identification de ses caractéristiques et l'encodage du stimulus sont en général plus connues que les étapes ultérieures où les individus doivent sélectionner et programmer la réponse appropriée (Schmidt, 1988).

Le rôle de l'attention comme déterminant des temps de réponse demeure à clarifier mais il est probablement déterminant dans les deux premiers stades du modèle de traitement de l'information cité plus haut. En général, l'éveil et l'attention peuvent être vus comme des substrats de la performance de toutes les tâches conscientes. Il n'y a donc pas de test unique de l'attention fonctionnelle. Tous les tests doivent s'en remettre à la détection de performance au sein de tâches motrices, perceptuelles ou cognitives. La capacité attentionnelle est une entité limitée pouvant être allouée avec flexibilité à une ou plusieurs tâches. Le contrôle stratégique de l'attention permet l'allocation de l'attention en accord avec un plan d'action et la complétion de tâches spécifiques.

En ce qui a trait à la réponse motrice composant le temps de réponse, il semble y avoir un certain consensus à l'effet que ces réponses sont contrôlées par des programmes moteurs (Schmidt, 1988). Cependant le mode de contrôle de ces programmes moteurs n'est pas clair. Longtemps, on a cru à l'existence d'un programme moteur pour chacun des mouvements à exécuter, que tout était décidé avant le début de l'exécution des mouvements par des programmes internes qui devaient être activés (Henry & Rodgers, 1960). Une réinterprétation plus récente de certaines de ces données semblerait indiquer que le temps de programmation est affecté par les effets cumulatifs des contraintes placées sur le système moteur. Par exemple, une demande de précision plus grande fera augmenter le temps de programmation et ce, parce qu'il y aura une demande supplémentaire d'organisation neuronale et d'inhibition d'activité motrice non désirable (Sidaway et coll., 1988). De plus, lorsqu'étudiée pour des mouvements de complexité croissante (impliquant plus de deux ou trois segments corporels), la relation directe décrite par Henry (1960) ne se retrouve pas aussi clairement (Christina et coll., 1985). Ceci semblerait suggérer qu'une certaine partie de la programmation pourrait prendre place après l'initiation du mouvement (Norril, 1974; Anson, 1982; Klapp & Wyatt, 1976; Eason & Surburg, 1993). Plus récemment, Rosenbaum (1988) proposait un modèle de programmation rendant compte du potentiel de programmation "en-ligne" soit après l'initiation du mouvement lui-même, le modèle du "hierarchical editor".

En général, le TR peut être diminué si on permet à l'individu un temps ou stimulus de préparation, et peut être augmenté par des stimuli d'interférence, la fatigue ou potentiellement des dommages cérébraux. Le TM est quant à lui déterminé par la capacité de l'individu à accélérer les segments du corps impliqués dans la réponse motrice. Il peut être amélioré par la pratique répétitive du mouvement. Globalement, les temps de réponse peuvent donc être compromis par un dommage à n'importe lesquelles des structures impliquées dans leur production tant au niveau de la perception sensorielle de l'information qu'au niveau de la programmation ou de l'exécution motrice. C'est pourquoi des lésions cérébrales engendrées par un TCL ont le potentiel d'affecter les temps de réponse. La section qui suit se penche précisément sur ces études s'étant intéressées à examiner les temps de réponse suite à ce type de traumatisme.

2.3.4.2.2 Les temps de réponse et le TCL

Les tests neuropsychologiques qui sont administrés aux patients suite à un TCC comprennent habituellement des items traitant de la vitesse de réaction mais dans un contexte plus global de détection de lenteur du traitement de l'information ou de troubles attentionnels. Il est généralement reconnu que les individus, tant enfants qu'adultes, ayant subi des TCC modérés ou sévères présentent un ralentissement général des TR avec une préservation relative des TM lorsque testés à l'aide de différents paradigmes. De plus, les sujets post-TCC sévères semblent présenter des difficultés en situation où la performance doit s'effectuer lors de contraintes de temps (Cicerone, 1997). Une controverse demeure cependant quant à un stade particulier de traitement de l'information qui serait affecté de manière spécifique par le TCC (Shum et coll., 1990; Murray et coll., 1992; Stablum et coll., 1994). Un déficit non spécifique de traitement de l'information serait cependant en accord avec la nature diffuse des dommages (e.g. lésions axonales diffuses) lors de TCC sévères (Stokx & Gaillard, 1986; Ponsford & Kinsella, 1992; Van Zomeren, 1994; Hetherington et coll., 1996; Zahn & Mirsky, 1999).

En ce qui a trait au TCL, où les individus présentent peu de déficits lors de l'administration de tests neuropsychologiques standardisés (incluant des épreuves de traitement de l'information) tel que discuté antérieurement dans la section des capacités cognitives, l'existence du ralentissement global des processus cognitifs identifié chez les TCC sévères n'est pas relevé de manière aussi concluante. Chez les individus adultes, Montgomery et coll. (1991) identifient une augmentation des TR moyens d'environ 300ms (utilisant un TR à quatre choix) chez un groupe de 26 adultes post-TCL 24 heures après le traumatisme lorsque comparés à ceux des contrôles. Les sujets TCL s'améliorent au cours des semaines qui suivent mais conservent des TR prolongés (100ms) lorsque comparés aux contrôles, six semaines post-trauma. Shum et coll. (1990) par contre, comparèrent un groupe de sept adultes avec TCL et des contrôles sains environ un mois post-trauma, utilisant divers paradigmes de temps de réponse au choix et ne trouvèrent aucune différence significative entre les deux groupes malgré des TR légèrement supérieurs chez le groupe TCL.

Les études s'étant penchées sur les temps de réponses visuo-motrices chez les enfants suite à un TCL sont encore plus éparses. Murray et coll. (1992) prolongeant les travaux de Shum et coll. (1990) et utilisant les mêmes tâches que Shum, trouvèrent qu'un groupe de 10 enfants post-TCL présentaient des TR augmentés lorsque comparés à des enfants contrôles mais que ces augmentations n'atteignaient pas un niveau statistiquement significatif. Il est intéressant de noter cependant que les évaluations faites dans le cadre de cette étude (Murray et coll., 1992) prirent place un an après le TCL, dépassant ainsi la période aiguë où les problèmes sont les plus susceptibles de se présenter. Des travaux plus récents faits par notre groupe dans le cadre de l'étude exploratoire décrite dans la section des capacités motrices générales révélèrent que des enfants TCL évalués deux semaines après le TCL présentaient des ralentissements de temps de réponse sur une tâche visuo-motrice faisant partie du Bruininks-Oseretsky Test of Motor Proficiency, lorsque comparés aux normes publiées pour ce test standardisé.

Dans les travaux cités jusqu'à maintenant, les enfants, tout comme les adultes, sont généralement testés dans une position stable où on leur demande de répondre à des stimuli visuels ou auditifs à l'aide de réponses motrices de faible amplitude exécutées par les membres supérieurs et ne requérant que peu de segments corporels. Ces situations de test, bien qu'appropriées pour l'investigation de processus de ralentissement cognitif, sont loin de reproduire les situations auxquelles les enfants font face dans leur vie de tous les jours, ou dans la pratique de leurs activités physiques. En effet, les activités physiques regorgent de situations où les enfants doivent non seulement réagir rapidement mais avec des mouvements impliquant des déplacements de leur centre de gravité, donc de plus large amplitude (Chamberlin & Magill, 1989). Une méthode pour tester les temps de réponse prenant en considération ces caractéristiques est donc essentielle pour tirer des conclusions pouvant s'appliquer aux temps de réponse nécessaires à la pratique des activités physiques (Harbin et coll., 1989).

Johnson et coll. (2002) se pencha sur la mesure de l'agilité d'athlètes collégiaux ayant subi un TCL à exécuter des mouvements dynamiques tels ceux requis dans la pratique des activités physiques. Dans cette étude, les individus devaient réagir de manière appropriée à des stimuli visuels en sautant (mouvements du corps tout entier) sur un tapis composé de 14 cibles. Le temps moyen pour compléter 25 déplacements consécutifs sur les cibles fut enregistré. Les athlètes exécutaient cette tâche en période pré-saison et une nouvelle fois après un TCL, si un tel traumatisme était subi pendant la saison. Aucune différence significative ne fut trouvée entre les athlètes blessés et ceux composant un groupe contrôle recruté parmi les athlètes non blessés. Aucune étude impliquant de telles tâches effectuées avec des enfants ayant subi un TCL n'a pu être recensée dans les écrits même si les enfants d'âge scolaire sont le segment le plus actif de la population et qu'il serait important d'avoir de telles données. Notre étude pilote suggérant la présence de troubles de temps de réponse et d'équilibre après un TCL, ceci pourrait avoir un impact sur leur capacité à répondre rapidement et adéquatement avec des mouvements de déplacement impliquant le corps en entier. De plus, il est démontré que les enfants ayant subi un TCL sont généralement plus à risque de subir un TCC subséquent que des enfants avec blessures orthopédiques et ce, jusqu'à un an post-trauma (Swaine & Marosi, 2002). Les difficultés d'équilibre combinées à des temps de réponse augmentés pourraient peut-être rendre les enfants plus à risque de se blesser à nouveau. Dans ce contexte il est justifié d'examiner les temps de réponse des enfants post-TCL.

2.3.4.3 L'équilibre

2.3.4.3.1 Définition et contrôle de l'équilibre

Le contrôle de l'équilibre est un préalable à la réussite de plusieurs activités de la vie quotidienne et un facteur déterminant pour l'indépendance d'un individu (Bohannon et coll., 1984). Dans le contexte de tâches spécifiques et pour le maintien de postures, l'équilibre peut être défini comme la condition où toutes les forces et les moments agissant sur le corps se contrebalancent. Ceci fait en sorte que le centre de masse d'un individu se maintient dans les limites de sa stabilité (sommairement définies par son polygone de sustentation) (Horak, 1987; Woollacott & Shumway-Cook, 1996; Horak et coll., 1997). Le contrôle postural peut quant à lui être défini comme le processus par lequel le système nerveux génère les chaînes d'activité musculaire requis pour ajuster le centre de masse par rapport à la base de support (Maki & McIlroy, 1996).

Pour maintenir une posture ou assurer des transitions appropriées entre différentes positions, le système nerveux doit gérer rapidement des informations sensorielles provenant d'une variété de sources (e.g. visuelles, vestibulaires, proprioceptives, tactiles). Il doit ensuite utiliser ces informations de manière sélective pour générer des réponses motrices complexes ajustées dans leur séquence, direction et amplitude, aux caractéristiques d'une situation et aux contraintes de l'environnement. Il s'agit donc de produire les ajustements nécessaires lors de mouvements volontaires ou de perturbations externes (Horak et coll., 1997). Le contrôle postural peut s'effectuer de manière proactive (i.e. feedforward), permettant d'anticiper ces perturbations, de manière réactive (i.e. feedback), en réponse à ces perturbations mais le plus souvent, par la combinaison de ces deux modes de contrôle (Horak et coll., 1997). Dans tous les cas, il appartient au système nerveux de prédire ou de détecter les instabilités et de produire les mouvements appropriés pour les contrebalancer (Maki & McIlroy, 1996). Les mouvements produits pour y arriver furent identifiés dans le cadre d'études sur le contrôle de l'équilibre et sont regroupés en deux classes principales: les synergies musculaires et les stratégies de mouvement (Nashner, 1977; Horak & Nashner, 1986; Macpherson, 1991).

Nashner & McCollum (1985) décrivent les synergies musculaires comme des patrons stéréotypés d'activité musculaire en réponse à une translation ou une rotation de la surface de support d'un individu. Ces synergies seraient organisées au niveau central et répondraient aux conditions initiales dans lesquelles se trouve l'individu, à la perturbation elle-même, à l'apprentissage et à l'attention. Les stratégies de mouvement sont quant à elles des solutions sensori-motrices plus générales au contrôle de la posture. On classe ces stratégies en trois catégories: la stratégie de cheville, de hanche et de "stepping". La stratégie de cheville a pour but de maintenir le tronc érigé et serait particulièrement sensible aux informations somatosensorielles (bien que les informations vestibulaires et visuelles ne puissent être exclues). En effet, des sujets privés de ce type d'information sensorielle soit par bloc ischémique, soit suite à une neuropathie périphérique, seraient incapables d'initier une stratégie de cheville efficace et auraient tendance à utiliser une stratégie autre (Horak et coll. 1990; Inglis et coll., 1994; Horak et coll.1997). La stratégie de hanche a, quant à elle, pour objectif comportemental de contrer les déplacements rapides du centre de masse de l'individu. On estime que les informations vestibulaires ont un rôle important à jouer lors de l'initiation de cette stratégie car les individus ayant une absence d'information vestibulaire sont incapables d'utiliser cette stratégie même en condition de base de support très restreinte (Horak et coll., 1990). La stratégie de "stepping" qui répond à des perturbations plus grandes ou sans contrainte de surface de support rend possible la création d'une nouvelle base de support afin de prévenir une chute (Nashner & McCollum, 1985; Horak & Nashner, 1986). Ces stratégies ne seraient pas des réflexes avec connections bien définies, mais plutôt des habiletés apprises. Horak et coll. (1992; 1996). En effet, Horak et Macpherson (1996) les définissent comme un continuum de processus qui fournissent un plan d'action global, basé sur des buts précis, ancré dans un environnement spécifique, adapté à une tâche particulière et utilisant les informations sensorielles disponibles.

On reconnaît aujourd'hui la contribution de trois systèmes sensoriels principaux au maintien de l'équilibre. D'abord le système visuel qui fournit de l'information sur la position et le mouvement du corps d'un individu dans l'environnement et de l'information sur l'environnement extracorporel à savoir la position et les mouvements des objets dans l'espace autour de l'individu (Stoffregen,1985; Wade & Jones, 1997). Ensuite le système vestibulaire qui, à l'aide des otolithes et des canaux semi-circulaires, fournit des informations sur la position de la tête en relation avec la gravité, sur la verticalité du corps, et sur ses mouvements d'accélération et de décélération (Black et coll., 1983). Ce système apparaît comme une référence interne du corps et serait celui ayant un rôle prépondérant dans la résolution de conflits sensoriels. Il est le dernier à atteindre sa maturité et celui qui répond à des mouvements de plus hautes fréquences. Ce n'est que vers l'âge de 7 à 10 ans que l'enfant apprend à utiliser le système vestibulaire de manière appropriée dans la résolution de conflits sensoriels. Finalement, le système somatosensoriel (tactile, proprioception des muscles et tendons, récepteurs des articulations) procure des informations au sujet de la pression présente sur la surface plantaire, de la longueur et de la tension des muscles, et sur la position des articulations du corps. Ce système est probablement la source dominante d'informations sensorielles dans des conditions de surface de support stable (Woollacott et coll., 1989; Forssberg & Nashner, 1982; Shumway-Cook & Woollacott, 1985; Burton & Davies, 1992).

Les informations provenant des systèmes sensoriels sont d'une importance capitale dans le contrôle postural. Comme les individus normaux maintiennent un équilibre adéquat sous une grande diversité de conditions en supprimant rapidement, l'influence des systèmes sensoriels fournissant de l'information erronée, les mécanismes d'interaction ou d'intégration des informations multimodales utilisées pour le contrôle postural ont aussi fait l'objet de plusieurs travaux. Même si l'information d'un système sensoriel est inappropriée, le problème crucial en contrôle de posture est de réussir à moduler ou à peser l'information existante de manière appropriée en présence de conflits entre les systèmes sensoriels. En général les adultes sans incapacités sont capables de faire cet ajustement (Nashner, 1976; Nashner & Berthoz, 1978; Nashner et coll., 1982; Shumway-Cook & Woollacott, 1985). Plusieurs hypothèses telles la redondance (Berthoz, 1978; Diener & Dichgans, 1988), le poids sensoriel de chaque modalité (Horak et coll., 1994; 1996; Zacharias & Young, 1981), ou encore la sommation vectorielle sont posées pour expliquer le processus d'intégration et d'interaction sensorielle.

L'âge d'un individu joue un rôle important au niveau du contrôle postural. Les nouveau-nés, enfants, adultes et personnes âgées ne démontrent pas les mêmes stratégies quant au maintien de leur équilibre. Par exemple, les changements dus à la maturation (myélinisation du système nerveux, développement des récepteurs proprioceptifs, etc.) présents aux cours des premières années de la vie affecteront l'équilibre de manière à optimiser l'utilisation des systèmes disponibles à chaque étape du développement. Le système visuel occupe une place particulièrement importante dans le contrôle postural chez l'enfant entre quatre mois et deux ans

(Riach & Hayes, 1990). Ce n'est qu'entre l'âge de trois et six ans que les enfants arriveront à utiliser les informations somatosensorielles et vers 7 à 10 ans, qu'ils se référeront à leur système vestibulaire pour la résolution de conflits sensoriels en démontrant les mêmes stratégies de mouvement que les adultes (Woollacott et coll., 1989; Forssberg & Nashner, 1982; Shumway-Cook & Woollacott, 1985; Burton & Davies, 1992).

Vu la complexité du phénomène du maintien de l'équilibre, des problèmes d'équilibre peuvent être causés par une lésion ou une dysfonction à n'importe laquelle des composantes discutées ici. Il n'est donc pas surprenant que l'équilibre se démarque de plus en plus comme domaine d'intérêt chez les individus ayant subi un TCC, même léger.

2.3.4.3.2 L'équilibre et le TCL

En général, on reconnaît la présence de troubles de l'équilibre chez les individus ayant subi un TCC de plus grande sévérité. Ce type de traumatisme, de par sa nature, produit des déficits à plusieurs systèmes résultant en une variété de désordres cognitifs, comportementaux et du mouvement affectant l'équilibre (Shumway-Cook & Olmscheid, 1990, Hillier et coll., 1997; Cecchini, 1998; Tolfts & Stiller, 1997; Wade & Jones, 1997). Les écrits sont très épars sur le sujet de l'équilibre chez les personnes ayant subi un TCL, adultes et enfants. Comme souligné dans une section antérieure, le TCL est généralement considéré comme ne laissant que peu de problèmes moteurs. Pour cette raison, l'évaluation spécifique et standardisée de l'équilibre ne fait l'objet que de peu d'études.

Chez les adultes, on recense trois groupes s'étant penchés sur le sujet de l'équilibre suite au TCL. Geurts et coll. (1996; 1999) entreprirent de d'évaluer l'équilibre de 20 sujets TCC, dont 13 légers, à l'aide de mesures des variations du centre de pression en position debout sur des plate-forme de force en les comparant à 20 sujets sains. Comparés aux sujets contrôles, les sujets TCC présentaient une augmentation de plus de 50% d'oscillations dans les plans antéro-postérieurs et latéraux, et la perte d'informations visuelles (yeux fermés) étaient la condition les affectant le plus. Ces déficits étaient présents sans problèmes neurologiques spécifiques ni de problèmes détectables à l'aide de tests neuropsychologiques (Geurts et coll., 1999). Les hypothèses quant aux bases neurologiques de ces déficits posturaux même chez les cas de TCL, sont à l'effet que les patients peuvent avoir besoin de plus de temps pour traiter l'information dû à une lenteur de l'activité sous-corticale. Ceci pourrait mener à des oscillations posturales excessives et une utilisation accrue des informations visuelles pour le maintien de la posture. De plus, la vision voulant que les lésions axiales diffuses (LAD) présentes après un TCC le soient dans un continuum à travers les divers degrés de sévérité pourrait expliquer que ces problèmes de posture soient reliés à des LAD plus mineures mais diffuses au niveau, par exemple, du tronc cérébral ou du cervelet. Finalement, les auteurs terminent en soulignant que bien que ces problèmes mineurs ne soient pas responsables d'incapacités sérieuses en elles-mêmes, elles peuvent interagir avec d'autres, mineures elles aussi, pour expliquer les effets à long terme des TCL.

Guskiewicz et coll. (1997) s'intéressèrent aussi au contrôle postural après le TCL et évaluèrent une population d'athlètes 1, 3, 5 et 10 jours post-trauma au niveau cognitif (tests neuropsychologiques reconnus) et de l'équilibre à l'aide d'un test appareillé soit l'oscillation du centre de masse lors de l'exposition à des stimulations sensorielles visuelles, proprioceptives et vestibulaires (Sensory Organization Test du Neurocom Smart Balance Master) (Guskiewicz et coll., 1997). Les athlètes testés démontraient en moyenne, une performance en deçà de celle d'un groupe contrôle jusqu'au troisième jour post-trauma avec un retour à la normale par la suite. De par la présence de déficits lors de conflits sensoriels, les auteurs conclurent à un problème potentiel d'organisation sensorielle. Encore une fois, les résultats des tests cognitifs quant à eux ne démontraient aucun déficit au cours de la même période, soulignant ici la présence de problèmes d'équilibre chez des sujets ne présentant aucun des symptômes plus communément reconnus.

Finalement, Mrazik et coll. (2000), relevèrent des différences significatives entre quatre athlètes ayant subi des TCL de grades différents au niveau de leur performance au même test utilisé par Guskiewicz et coll. (i.e.SOT) et une série de tests neuropsychologiques. L'individu ayant subi une commotion de grade 3 (la plus sévère) ainsi que celui dont le TCL n'était pas le premier présentaient des symptômes post-commotionnels persistants sur une période de deux semaines. Pour ce qui était des résultats aux tests neuropsychologiques et au test d'équilibre, les deux mêmes individus présentaient aussi des déficits bien que ceux-ci aient atteint leur niveau pré-traumatique au cours de la première semaine.

Chez la population pédiatrique, l'étude exploratoire effectuée par notre groupe (Gagnon et coll., 1998), décrite dans la section des capacités motrices générales, est la seule recensée évaluant de manière spécifique et standardisée la performance motrice, comprenant une section sur l'équilibre. Rappelons que plus de 40% des enfants présentaient une performance diminuée au niveau de l'équilibre lorsque comparée aux normes disponibles pour leur groupe d'âge deux semaines après le TCL.

En conclusion, bien que la question des incapacités motrices suite au TCL pédiatrique demeure non élucidée, suffisamment d'évidences existent pour justifier l'étude spécifique des troubles potentiels d'équilibre et de temps de réponses chez cette clientèle. De plus, ces capacités sont des pré-requis à la performance d'activités physiques de toutes sortes, habitude de vie centrale chez les enfants. Leur étude est justifiée dans le contexte du retour sécuritaire et satisfaisant des enfants à leurs activités physiques post-TCL.

2.4 Retour aux activités physiques après un TCL

La question du retour aux activités physiques après un TCL est habituellement traitée du point de vue du temps de guérison optimal suite au traumatisme. La plupart des recommandations concernant un moment de retour considéré comme sécuritaire émanent des études faites avec les athlètes d'élite, pour qui le moment du retour revêt une importance particulière de par la nature de leur implication sportive (CIS, 2002; Johnston et coll., 2001). Les consignes varient tant en terme de temps où les activités devraient être restreintes qu'en termes des critères permettant le retour au jeu mais sont toutes ajustées selon le niveau de sévérité du TCL (grade). Les recommandations provenant des paramètres de pratique de l'AAN (1997) sont inclus à titre d'exemple au tableau 3.

TABLEAU 3: Recommandations de prise en charge et de retour au jeu après un traumatisme crânio-cérébral léger chez une clientèle athlétique selon l'American Academy of Neurology (AAN, 1997).

Grade du TCL	Évaluation au site de l'activité	Évaluation neurologique	Retour au jeu le même jour	Consignes de retour au jeu (i.e. temps d'arrêt)*
Grade 1	Oui	Non-requise, peut-être demandée selon l'état clinique	Oui si l'évaluation, incluant un examen de l'état cognitif, est normale au repos et à l'activité	Retour le même jour si 1er TCL de grade 1, sinon 1 semaine
Grade 2	Oui	Oui	Non	1 semaine si 1er TCL de grade 2, sinon 2 semaines
Grade 3	Oui	Oui	Non	1 semaine si période de perte de conscience était de quelques secondes; 2 semaines si la période de perte de conscience dépassait 1 minute; 1 mois ou plus si plus d'un TCL de grade 3 dans la saison

* Seulement si l'individu ne présente aucun symptôme et un examen neurologique normal au repos et après un essai d'exercice.

On recense une publication de telles consignes de retour aux activités physiques pour la clientèle pédiatrique dans le cadre de recommandations plus générales concernant tous les domaines de la vie de l'enfant (e.g. académique, loisirs) (Swaine & Friedman, 2001) et basées sur celles développées pour la clientèle athlétique. Ces recommandations sont largement utilisées mais aucune étude ne prouve leur efficacité. En général, on y retrouve des restrictions d'activités physiques d'une durée de deux à quatre semaines selon le grade de sévérité du TCL et celles-ci ont la particularité de ne pas se limiter aux enfants impliqués dans des activités sportives de haut niveau, mais bien de s'adresser à la population pédiatrique en général, tenant compte du fait que les enfants participent généralement à une multitude d'activités. La sécurité semble donc être un facteur préoccupant pour les intervenants. Le détail de ces recommandations, développées et utilisées au sein de l'établissement hospitalier d'où provenaient les sujets recrutés pour la présente étude est présenté en annexe A.

Une fois passée la période de restriction, les enfants retournent à leurs activités physiques car celles-ci sont un phénomène social important chez les enfants et représentent probablement une des habitudes de vie où la majorité des enfants passent le plus de temps, outre les activités académiques (Kino-Québec, 2000). Par contre, selon les cliniciens impliqués dans le programme de neurotraumatologie de l'Hôpital de Montréal pour Enfants, quelques enfants semblent eux-mêmes identifier des insatisfactions face à la qualité de leur performance une fois les activités reprises suite au traumatisme, bien que celui-ci soit qualifié de mineur par la plupart des intervenants et des gens de leur entourage. Cette question de la performance dans les activités physiques chez les enfants, ou même chez les adultes, post-TCL génère peu d'intérêt dans les écrits. Avant de discuter spécifiquement de la pratique des activités physiques post-TCL, il apparaît essentiel de s'arrêter sur les déterminants de la participation et de la performance susceptibles d'être sensibles au TCL.

2.4.1 Déterminants de la participation et de la performance

Au cours des deux dernières décennies, on retrouve un intérêt soutenu pour les questions touchant la participation aux activités sportives, spécifiquement en regard des facteurs poussant les individus à initier, poursuivre ou cesser la pratique de celles-ci et ce, même chez la population pédiatrique (Gould, 1982; Horn, 1992). Cependant, comme chez les adultes, les études publiées dans ce domaine sont surtout limitées aux activités sportives structurées (organisées) comprenant souvent une composante compétitive, et ces études ne s'intéressent que peu au large éventail d'activités récréatives auxquelles les enfants participent sans structure ou surveillance particulière (Horn, 1992). Malgré ces limites, il est généralement reconnu que le choix de participer ou non aux activités physiques ainsi que le niveau de performance atteint lors de la pratique de ces activités sont des concepts influencés par plusieurs déterminants, incluant des déterminants physiques tels la force, la souplesse, l'équilibre ou les habiletés athlétiques comme telles, mais aussi des déterminants plus psychosociaux incluant la motivation, la compétence ou l'efficacité personnelle dans le contexte de situations spécifiques. Ces capacités, tant motrices que psychosociales pourraient être affectées suite à une blessure telle un TCL et constituer une raison pour laquelle les enfants sembleraient moins confiants ou performants suite au trauma. Deux des déterminants physiques ayant été discutés au sein des sections antérieures, la suite de cette partie s'attardera surtout à deux déterminants psychosociaux influençant la pratique et la performance des activités physiques: d'abord la perception de la compétence athlétique, ensuite l'efficacité personnelle en regard des activités physiques.

2.4.2 La perception de la compétence athlétique

La perception de la compétence telle que définie par Harter (1982; 1984) dans le cadre de sa théorie de la compétence et de la motivation réfère à une perception globale des habiletés particulières à plusieurs sous-domaines (physique, social, académique, etc.) menant à une appréciation globale de la compétence d'un individu. Les jugements concernant ces sous-domaines de compétence seraient obtenus grâce à l'implication d'un individu au sein d'une activité. Si couronnée de succès, cette participation résulterait en des sentiments positifs qui renforceraient la motivation de l'individu à poursuivre l'activité. Pour la compétence athlétique, par exemple, les individus possédant un niveau de compétence athlétique élevé exerceront plus d'effort et persisteront plus longtemps au sein d'activités physiques que ceux démontrant un niveau moins élevé de compétence (McKiddie & Maynard, 1997). La perception de la compétence athlétique est un construit central dans la recherche sur la participation aux activités physiques même chez les enfants. En effet, Butcher et coll. (2001) démontrèrent que des enfants de 8 à 10 ans qui participaient à des sports et activités physiques de manière régulière possédaient une perception de compétence athlétique plus élevée que leurs pairs non participants.

2.4.3 L'efficacité personnelle

Comme la théorie de Harter sur la perception de la compétence, la théorie de l'efficacité personnelle de Bandura (1986) s'intéresse aussi au concept de motivation, mais plutôt centrée sur la maîtrise et la réalisation d'activités spécifiques. L'efficacité personnelle est parfois utilisée pour faire référence au sens général de compétence d'un individu (Smith et coll., 1990; Cowen et coll., 1991), se rapprochant ainsi des notions comprises dans le modèle de compétence personnelle de Harter. Cependant, l'efficacité personnelle est plus utile lorsque définie, opérationnalisée, et mesurée dans l'optique d'une situation particulière (Bandura, 1986). En d'autres mots, il s'agirait moins d'un trait de la personnalité concernant un domaine global (académique, physique, social) mais bien d'un jugement individuel de sa capacité à réussir une tâche spécifique dans un contexte spécifique, par exemple réussir à atteindre des cibles lors de lancers de balle au cours d'éducation physique. Au cœur de cette théorie repose la notion que l'initiation et la persistance de la participation aux activités diverses sont déterminées d'abord par les jugements et attentes à propos des habiletés et capacités comportementales d'un individu de même que par les chances de répondre avec succès aux demandes et défis de l'environnement spécifique (Bandura, 1986). La théorie de l'efficacité personnelle se centre donc sur les aspects cognitifs de la maîtrise et de la performance (Bandura, 1986; Horn, 1992). Les croyances d'efficacité personnelle sont le produit d'informations provenant de quatre sources principales: 1) les expériences vécues, 2) les expériences observées et imaginées, 3) la persuasion verbale ou l'encouragement et 4) les états psychologiques et émotionnels d'un individu au moment d'entreprendre l'activité en question.

L'efficacité personnelle est donc d'emblée, une mesure de perception des capacités plutôt qu'une mesure réelle de la performance (Bandura, 1986, 1990). Les individus ont tendance à éviter les activités et les situations spécifiques qui, selon eux, excéderont leurs capacités à les gérer, mais s'engageront volontiers au sein d'activités qu'ils croient pouvoir réussir (Schunk, 1984; Betz & Hackett, 1986; Bandura, 1989). Ils auront tendance à interpréter les demandes et les obstacles rencontrés comme des défis plutôt que comme une menace ou des événements subjectivement incontrôlables (Bandura, 1990). L'anxiété face aux obstacles et difficultés est aussi largement dépendante des croyances à pouvoir contrôler les situations et environnements. En effet, l'obstacle n'est pas une propriété propre à un événement ou à une situation. Il s'agit plutôt d'une propriété relationnelle à propos du pairage entre les aspects menaçants de l'environnement et la perception des capacités à les affronter. Bandura est donc partisan d'une approche à la mesure de l'efficacité personnelle spécifique à une situation ou d'un comportement, soutenant qu'une mesure plus générale ne pourrait pas être adéquate pour capter le niveau d'efficacité requis pour répondre à des situations très spécifiques telles une maladie ou les sports particuliers.

Cet état de fait poussa plusieurs à se pencher sur l'efficacité personnelle d'individus atteints de conditions médicales diverses, présentant des défis particuliers. Dans le cas de la sclérose en plaques, par exemple, les études suggèrent que les gens ayant les plus hauts niveaux d'efficacité personnelle face à la gestion de leur condition sont les mieux ajustés et présentent moins de comorbidité psychologique (Schwartz et coll., 1996). Il en est de même chez les individus atteints d'épilepsie, où un plus haut niveau d'efficacité personnelle face à la gestion de leur condition semblerait lié à une meilleure capacité à gérer la condition en elle-même (Dilorio et coll., 1992). Des données récentes concernant la participation sociale post-TCC sévère semblent aussi indiquer que des facteurs dit de résilience tels l'efficacité personnelle générale auraient aussi un rôle essentiel dans le succès de la participation sociale de ces individus post-trauma (Dumont, 2003).

Malgré le fait que l'efficacité personnelle des individus post-TCL n'ait jamais fait l'objet d'études spécifiques ni dans le cadre de la participation sociale ni dans le cadre de la pratique des activités physiques, il est possible qu'elle soit affectée suite au traumatisme. Cette hypothèse est basée sur les travaux de Bandura qui constate que les athlètes possèdent tous des habiletés de base mais que leur perception d'efficacité personnelle affectera leurs performances lors de conditions de pression élevées, et par conséquent, leur succès. Les athlètes qui ont la capacité d'ignorer les facteurs émotionnels et stressants réussiront mieux que leurs pairs possédant des habiletés motrices équivalentes (Bandura, 1990). Vu cette association entre l'efficacité personnelle et la performance véritable, Bandura soutient que les blessures importantes pourraient affecter l'efficacité personnelle et ultérieurement affecter la performance de manière négative et ce, même après la résolution de la blessure initiale. Cette hypothèse fut supportée dans le cadre des blessures sévères ayant un effet permanent sur les capacités d'un individu mais pas dans le cadre de blessures musculo-squelettiques plus mineures ayant des répercussions limitées dans le temps (Weiss & Troxel, 1986; Kilgore 1998). Spécifiquement, Kilgore (1998) ne trouva aucun effet sur l'efficacité personnelle de blessures telles les étirements ligamentaires et blessures musculaires parmi les athlètes féminines de gymnastique lorsqu'évaluées avant chaque compétition au cours de la saison.

Somme toute, le manque de finalité des conclusions quant à la présence d'incapacités suite au TCL chez l'enfant et l'absence complète d'études en ce qui a trait à la participation et à la performance aux activités physiques post-trauma justifient l'entreprise de nos travaux. Ceux-ci se situent dans le cadre de l'examen du retour aux activités physiques après un TCL. Plus particulièrement, il s'agit d'étudier l'évolution de deux capacités motrices post-TCL: l'équilibre et les temps de réponse, et de deux capacités psychosociales ayant un rôle probable dans la pratique des activités physiques; l'efficacité personnelle reliée aux activités physiques et la perception de compétence athlétique. De plus, il sera intéressant d'examiner si des relations existent entre les différentes variables que nous aurons documentées. Ces questions de recherche sont formulées en tant qu'objectifs dans la prochaine partie, laquelle s'intéressera à la méthodologie générale des travaux expérimentaux.

CHAPITRE 3

MÉTHODOLOGIE DES TRAVAUX EXPÉRIMENTAUX

Cette partie sera consacrée à une description des méthodes utilisées au cours des travaux. Il s'agira d'abord de décrire les objectifs, méthodes (sujets, mesures et procédures d'acquisition des données) de l'étude principale et de présenter les articles scientifiques (articles 1-4) s'y rapportant en décrivant la problématique et les hypothèses propres à chacun. Suivra ensuite la méthodologie et la présentation de l'article (article 5) se rapportant à l'étude de comparaison des deux outils d'évaluation de l'équilibre.

3.1 Méthodologie générale de l'étude principale

3.1.1 Objectifs

Rappelons que l'*objectif principal* de cette étude était:
de décrire, au cours des 12 premières semaines suivant un TCL, les capacités d'équilibre et de temps de réponse, d'efficacité personnelle et de compétence athlétique d'un groupe d'enfants et de les comparer à celles d'un groupe d'enfants référence, non blessés, appariés pour l'âge, le sexe et le niveau d'activité physique pré-traumatique.

Les *objectifs secondaires* étaient:
1) d'examiner l'impact du TCL sur leur niveau de participation aux activités physiques telles les sports ou les jeux 12 semaines après le traumatisme et 2) d'examiner les relations entre les divers domaines étudiés soient: les caractéristiques socio-démographiques des enfants (e.g. âge, sexe), les caractéristiques du TCL (e.g. cause, grade de TCL), les capacités motrices (i.e. équilibre, temps de réponse) et psychosociales (i.e. compétence athlétique, efficacité personnelle) et le niveau de participation aux activités physiques.

3.1.2 Méthodes

Cette étude de cohorte consistait en deux groupes d'enfants et utilisait un devis prospectif pour l'évaluation de l'équilibre, des temps de réponse de l'efficacité personnelle, de la perception de la compétence athlétique et du niveau d'activité physique chez les enfants ayant subi un TCL. Pour assurer un contrôle de la maturation, des variations naturelles à la performance et des variables potentiellement confondantes (pré-traumatiques inconnues et non mesurées), les résultats étaient comparés à ceux d'un groupe d'enfants contrôles appariés pour l'âge, le sexe et le niveau d'activité physique pré-traumatique et recrutés, si possible, parmi les amis des enfants TCL.

3.1.2.1 Sujets

Un échantillon de 40 enfants ayant subi un TCL et un nombre égal d'enfants sans TCL, âgés entre 7 et 16 ans furent recrutés pour cette recherche. La taille de l'échantillon fut calculée en utilisant un niveau de signification alpha (α) de 0.05 et une puissance ($1-\beta$) de 0.80. L'outil de mesure principal était le sous-test d'équilibre du Bruininks-Oseretsky Test of MotorProficiency, utilisé dans le cadre de l'étude pilote (Gagnon et coll., 1998). Pour la détection d'une différence considérée comme significative entre les deux groupes, un échantillon de 38 sujets fut considéré comme nécessaire, selon la formule suivante où z = écart-type obtenu dans l'étude pilote; $\mu 1-\mu 2$ = différence significative entre les performances; α = niveau de signification fixé et $1-\beta$ = puissance fixée (Kelsey et coll., 1986).

$$n_1 = n_2 = \frac{2\,\alpha^2\,(z_{\alpha/2} - z_{\beta}^2}{(\mu 1 - \mu 2)^2}$$

Afin de permettre une marge d'erreur raisonnable et la possibilité de données incomplètes, un échantillon de 40 enfants par groupe fut recruté.

Les critères d'inclusion pour le groupe TCL étaient:

- Un diagnostic de TCC léger, tel que défini par l'American Congress of Rehabilitation Medicine (ARCM, 1993)
- La connaissance fonctionnelle du français ou de l'anglais

- La capacité à marcher de manière indépendante et sécuritaire

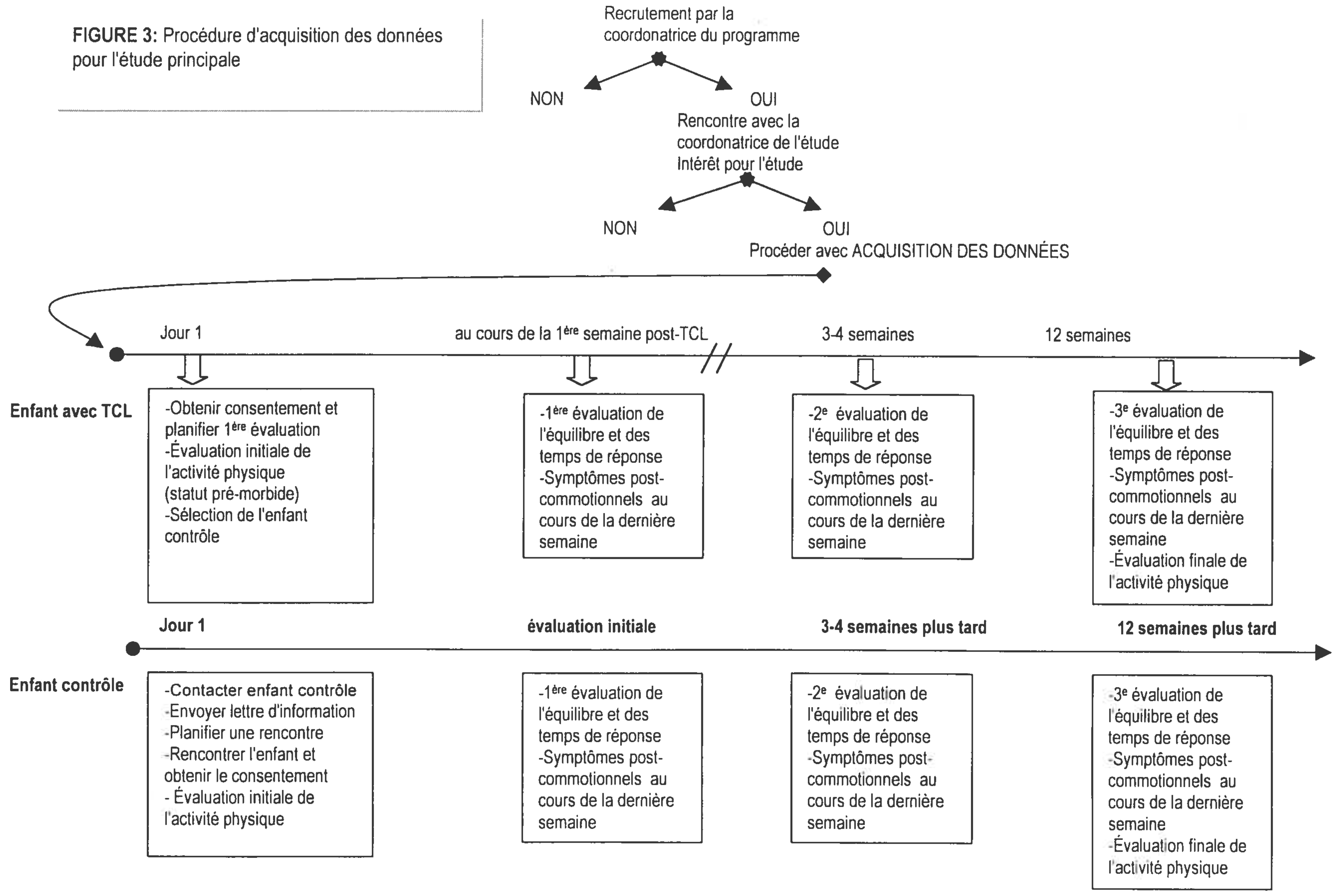
Les enfants furent exclus de l'étude s'ils présentaient:

- Un condition pré-traumatique affectant la performance motrice, telle une condition neuro-musculaire, musculosquelettique ou cardio-vasculaire, limitant l'évaluation.
- Un diagnostic médical pré-traumatique documenté de troubles d'apprentissage ou de déficit de l'attention avec ou sans hyperkinésie, ainsi que l'utilisation régulière de Ritalin.
- La présence à une école spéciale pour troubles d'apprentissage et/ou de comportement.
- Une fracture ou une comorbidité (lésion nerveuse, lacérations, etc...) limitant l'évaluation de la performance motrice.

Les critères d'inclusion et d'exclusion (excepté le diagnostic de TCL) étaient les mêmes pour le groupe d'enfants contrôles.

Les sujets du groupe TCL furent recrutés au cours de leur admission au programme de Neurotraumatologie de l'hôpital de Montréal pour enfants du Centre de Santé de l'Université McGill. La coordonatrice du programme rencontrait les familles et leur fournissait des explications au sujet du projet (annexe B.1). Après qu'ils eurent signifié leur intérêt à l'étude, la coordonatrice de l'étude rencontrait les parents et l'enfant dans le but d'expliquer les procédures, d'obtenir le consentement éclairé des parents et de l'enfant (annexe C.1), et de débuter l'acquisition des données telle que décrite à la figure 3. Le recrutement du groupe contrôle se faisait, si possible, parmi les amis du sujet TCL pour ainsi contrôler encore mieux des variables pré-traumatiques.

FIGURE 3: Procédure d'acquisition des données pour l'étude principale



3.1.2.2 Mesures

Un certain nombre de mesures de l'équilibre, de temps de réponse et d'activité physique ont été utilisées dans le cadre de cette étude. Les outils quantifiant les performances d'équilibre sont décrits dans les deux premiers articles. Le troisième article se concentre sur les résultats des temps de réponse et le quatrième sur les résultats concernant les données relatives aux activités physiques. Les outils utilisés pour évaluer les différents aspects de nos travaux sont les suivants:

Équilibre	• Bruininks-Oseretsky Test of Motor Proficiency-Balance (Bruininks, 1978) • Postural Stress Test (Wolfson et coll., 1986) • Pediatric Clinical Test of Sensory Integration for Balance (Crowe et coll., 1990; Westcott et coll., 1994)
Temps de réponse	• Bruininks-Oseretsky Test of Motor Proficiency-Response Speed (Bruininks, 1978) • Tapis d'interrupteurs pour évaluer le temps de réponse
Activités physiques	• Activity Rating Scale (Sallis et coll., 1988) (mesure d'appariement pour le niveau d'activités physiques) • Physical Activity Questionnaire for children or adolescents (Crocker et coll., 1997) • Athletic Competence subscale of the Self-Perception Profile for Children or Adolescents (Harter, 1985; 1988) • Questionnaire d'efficacité personnelle développé pour cette étude
Symptômes post-commotionnels	• Rivermead Post-Concussion Symptoms Questionnaire (King et coll., 1995)

Prises ensemble, ces mesures fournissent une évaluation globale des concepts d'intérêt. Un résumé des mesures ainsi que leurs qualités psychométriques sont fournies au tableau 4. Le détail de chacune de ces mesures est incluse au sein des articles.

TABLEAU 4: Caractéristiques et qualités des outils de mesures utilisés.

Domaine évalué	**Population testée** (âge en années)	**Construit mesuré**	**Contenu**	**Qualité psychométriques Fidélité**		**Validité**	
				Test-retest	Consistence interne.	Construit	Concourante
Équilibre							
Bruininks-Oseretsky Test of Motor Proficiency-Balance	4.5-14.5	Statique et dynamique sans perturbations externes	-8 items -cotation du temps passé dans une position, et critères passé/échoué	r=.56	r=.67	r_p = .57 test complet diff. Age, RM, DA	r_p = .52-.69 test complet (SCSIT)
Pediatric-Clinical Test of Sensory Integration for Balance	4-9 (test semblable existe pour les adultes)	Mesure le temps passé dans une position	-12 conditions sensorielles -mesuré en secondes maintenues	r_s= .45-.78 ICC= .79-.82	--	r_s= .63-.68 diff. DA, PC	--
Postural Stress Test	Adultes	Mesure de réponse aux perturbations externes standardisées	-mesuré en % de poids corporel requis pour déclancher une réaction de stepping	ICC=.71-.93	--	--	--
Temps de réponse							
Bruininks-Oseretsky Test of Motor Proficiency-Response time	4.5-14.5	Mesure le temps de réponse simple	-1 item -coté sur une échelle à 13 points	r=.60	n/a	r_p = .57 test complet diff. Age, RM, DA	r_p = .52-.69 test complet (SCSIT)
Appareil de temps de réponse (adapté pour cette étude)	Adultes	Évaluation des temps de réponse: -Réponses de faible amplitude -Réponses de plus large amplitude	-4 cibles s'allumant en séquence de 16 essais -mesuré en secondes	--	--	p<0.001 diff. amateur vs professionel (pour test original)	--

Domaine évalué	**Population testée** (âge en années)	**Construit mesuré**	**Contenu**	**Qualité psychométriques**			
				Fidélité		**Validité**	
				Test-retest	Consistence interne.	Construit	Concourante
Activités physiques							
Physical Activity Questionnaire Children/adolescents	8-18	Participation aux activités physiques au cours des 7 derniers jours	-questionnaire auto-administré -8 items (adolescents)ou 9 items (enfants) -coté sur échelle à 5 points -moyenne des items pour score total	r = .75 r = .82	Coeff. α=.83	r = .45-.48 (TRS)	r = .33-.73 (caltrac, ARS, LTEQ)
Athletic subscale of the Self-Perception Profile for Children or Adolescents	7-18	Perception de la compétence athlétique	-questionnaire auto-administré -5 items (adolescents) ou 6 items (enfants) -coté sur échelle à 4 points -moyenne des items pour score total		0.80 to 0.86 Cronbach's alpha		
Questionnaire sur l'efficacité personnelle (développé pour cette étude)		Efficacité personnelle reliée à la pratique des activités physiques	-questionnaire auto-administré -18 items séparés en 2 dimensions -coté sur échelle à 10 points -total des items pour score total pour chacune des dimensions				
Symptômes post-commotionnels							
Rivermead Post-Concussion Symptoms Questionnaire	Adultes	Présence et sévérité des syptômes post-commotionnels	-questionnaire -16 items -coté sur échelle à 5 points -total des items pour score total	r = .91			

ABBRÉVIATIONS r_s: spearman rank correlation; r:: pearson correlation; ICC: intra-class correlation; RM: retard mental; DA: difficultés d'apprentissage; TRS: Teacher's Rating Scale; CALTRAC: motion sensor; ARS: Activity Rating Scale; LTEQ: Leisure Time Exercise Questionnaire; SCSIT: Southern California Sensory Integration Test; PC: paralysie cérébrale

Les variables suivantes furent aussi documentées pour leur apport aux connaissances des caractéristiques du TCL et de l'enfant lui-même: l'information sur le type de traumatisme, les symptômes présents initialement et leur évolution dans le temps à l'hôpital, prises à partir du dossier médical et les informations socio-démographiques de l'enfant obtenues lors de la rencontre initiale.

3.1.2.3 Procédures générales

Les trois séances d'évaluation prirent place au domicile de l'enfant pour réduire les déplacements et les absences à l'école. Les choix des temps d'évaluation furent basés sur leur importance dans le processus de récupération (4 semaines marque la fin de la période de restriction d'activités et 12 semaines est rapporté comme le moment où la plupart des déficits sont résolus). Ces procédures sont aussi décrites en détails dans chacun des articles.

3.1.3 Présentation des articles relatifs à l'étude principale

3.1.3.1 Problématique de l'article 1: Étude d'un cas d'évaluation de l'équilibre pré et post-TCL

La présence de controverse quant à l'existence ou non d'incapacités suite à un TCL est alimentée en partie par le manque de données probantes sur l'état pré-traumatique des enfants tant au niveau psychologique que physique. Obtenir des informations sur l'état pré-traumatique des enfants ayant subi un TCL est une préoccupation constante pour les cliniciens et chercheurs impliqués auprès de cette clientèle. Au cours de la période de rodage des outils et des procédures de l'étude principale (rapportée dans les articles 2, 3 et 4), une des enfants évaluée subît un TCL dans le cadre d'une activité sportive de loisir. L'opportunité de décrire les performances à des tests d'équilibre avant et après le traumatisme s'est donc présentée. L'article 1 documente donc l'évolution des capacités d'équilibre de cette enfant au cours des 12 semaines suivant son TCL, en les comparant aux données pré-traumatiques disponibles.

3.1.3.2 Problématique de l'article 2: Évaluation de l'équilibre post-TCL

Le peu d'études disponibles concernant les capacités d'équilibre suite à un TCL rapportent des difficultés d'ordre dynamique et d'interaction sensorielle variant de quelques jours à plusieurs mois suivant le TCL tant chez les adultes (Geurts et coll., 1996; 1999; Guskiewicz et coll., 1997; Mrazic et coll., 2000) que chez les enfants (Gagnon et coll., 1998; 2001). L'objectif de cette partie de l'étude principale, présenté dans l'article 2, était de déterminer si les capacités d'équilibre des enfants étaient affectées au cours des trois premiers mois suivant le TCL lorsque comparées à celles d'un groupe d'enfants contrôles au cours de la même période. Afin d'obtenir le plus d'indices possibles quant aux aspects spécifiques de l'équilibre pouvant subir les effets du traumatisme, trois outils d'évaluation furent utilisés, chacun cernant un aspect particulier du contrôle postural. Le sous-test d'équilibre du BOTMP pour l'équilibre statique et dynamique sans perturbations externes, le PCTSIB pour l'interaction sensorielle en condition statique et le PST pour les réponses aux perturbations externes standardisées. L'hypothèse principale de cette partie était à l'effet que si des déficits d'équilibre étaient identifiés, ils seraient d'ordre plus dynamique que statique et plus complexes en termes d'interactions sensorielles que simples, tels qu'identifiés dans les études exploratoires antérieures.

3.1.3.3 Problématique de l'article 3: Évaluation du temps de réponse post-TCL

La vitesse de traitement de l'information étant directement liée à l'intégrité des connections intracérébrales, plusieurs chercheurs ont voulu démontrer les effets cognitifs d'un TCL à l'aide de la mesure des temps de réponse. Les résultats s'avèrent cependant souvent peu concluants et lorsque des augmentations des temps de réponse sont identifiées, les effets potentiels de telles augmentations sur les activités quotidiennes des enfants ne sont pas explorés. L'objectif de ce troisième article était de déterminer si les capacités de temps de réponse des enfants étaient affectées au cours des trois premiers mois suivant le TCL lorsque comparées à celles d'un groupe d'enfants contrôles au cours de la même période. Deux outils d'évaluation furent utilisés dans le but d'obtenir des informations plus complètes sur les temps de réponse: 1) le sous-test de vitesse de réponse du BOTMP pour un temps de réponse simple avec composante motrice limitée au membre supérieur et 2) un appareil développé pour notre étude évaluant le temps de réponse simple, au choix et au choix inversé avec réponse motrice soit limitée au membre supérieur, soit impliquant un déplacement du centre de gravité dans un mouvement global de tout le corps. L'hypothèse principale de cette partie était que des augmentations des temps de réponse seraient identifiées lors des épreuves plus complexes impliquant une réponse motrice de tout le corps, donc des composantes posturales et d'équilibre, plutôt que lors des épreuves plus simples limitées aux membres supérieurs.

3.1.3.4 Problématique de l'article 4: Évaluation du niveau de participation et de la perception de la performance aux activités physiques post-TCL.

Les études traitant du retour aux activités physiques suite à un TCL, tant chez les adultes que chez les enfants, s'intéressent surtout à la détermination d'un moment sécuritaire pour effectuer ce retour. La question de la participation et de la perception de la performance lors de la pratique des activités suite au TCL demeure non élucidée et constitue l'intérêt de ce quatrième article. En effet, les enfants eux-mêmes soulevant des inquiétudes face à leurs performances ou à la satisfaction qu'ils retirent de celle-ci post-TCL, il semblait d'un intérêt certain d'explorer certains aspects reliés à la participation et à la pratique des activités physiques. L'objectif de cet article était donc de déterminer si les enfants ayant subi un TCL maintenaient, 12 semaines post-trauma, un niveau d'activité physique, une perception de leur compétence athlétique et un niveau d'efficacité personnelle face à la pratique des activités physiques comparables à ceux de la période pré-traumatique et à ceux d'un groupe d'enfants contrôles. Bien que des évaluations directes de la performance des enfants lors de la pratique de leurs activités physiques n'aient pas été faisables dans le cadre de cette étude, les résultats pouvaient nous fournir des indices quant à celle-ci. Bien qu'il ne s'agissait que d'une étude exploratoire, en se basant sur les rapports des enfants, l'hypothèse de travail principale de cet article était à l'effet que la perception de la performance aux activités physiques allait être altérée suite au TCL.

3.2 Méthodologie de la dernière étude comparant deux outils d'évaluation de l'interaction sensorielle pour l'équilibre chez les enfants sains

3.1.1 Objectifs

L'objectif (article 5) de cette étude était de comparer la performance d'enfants sans pathologie à l'aide de deux tests évaluant l'organisation sensorielle pour le maintien de l'équilibre; le Sensory Organisation Test (SOT) du Smart Balance Master™ (Forssberg & Nashner, 1982), et le Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB) (Crowe et coll., 1990). Comme il est généralement accepté que le PCTSIB est une alternative clinique au SOT, notre hypothèse était que les enfants devraient démontrer des performances fortement corrélées pour ces deux tests. De plus, si les deux outils prétendent évaluer des niveaux variables de complexité de l'interaction sensorielle à l'aide des six mêmes conditions sensorielles, il était attendu que les performances des enfants seraient classées dans le même ordre dans chacun des deux tests. Un objectif secondaire de l'étude était d'examiner les relations entre l'âge des enfants et leurs performances aux deux tests.

3.1.2 Méthodes

Il s'agit d'une étude exploratoire de type transverse évaluant la performance d'un groupe d'enfants sains aux deux tests d'équilibre.

3.1.2.1 Sujets

Un échantillon de convenance de seize sujets volontaires sains ont participé à cette étude. Les enfants étaient âgés entre 6 et 16 ans et étaient recrutés parmi les enfants du personnel du centre de recherche de l'IRM, de l'Hôpital de Montréal pour Enfants, et parmi les amis des chercheurs. Ce groupe d'âge fut choisi en particulier pour assurer une plus grande variabilité de performances, attendue de par une maturité différente du développement dans le domaine de l'équilibre. Les critères d'inclusion étaient:1) être âgé entre 6 et 16 ans, 2) être en bonne santé et 3) pouvoir se déplacer au Centre de Recherche Interdisciplinaire en Réadaptation, site de l'institut de réadaptation de Montréal. Les enfants étaient exclus s'ils présentaient: 1) des antécédents médicaux tels une condition neurologique ou orthopédique pouvant influencer le maintien de l'équilibre 2) un diagnostic de trouble de l'attention empêchant la participation au protocole d'évaluation, 3) la fréquentation d'une classe scolaire autre que celle prévue pour son groupe d'âge ou 4) des difficultés rapportées par les parents lors de la participation à des activités sportives.

Les parents des enfants éligibles à l'étude et intéressés à participer, recevaient une lettre d'information (annexe B.2). Après avoir signifié leur intérêt à participer, une séance d'évaluation était planifiée où les parents et les enfants étaient rencontrés pour répondre à leurs questions et obtenir leur consentement (annexe C.2) avant de procéder à l'acquisition des données.

3.1.2.2 Mesures

Deux instruments de mesure de l'équilibre étaient utilisés pour cette étude; le Sensory Organization Test (SOT) du Smart Balance Master™ et le Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB). Les conditions sensorielles évaluées à l'aide des deux tests étaient les mêmes et sont présentées au tableau 5.

3.1.2.3 Procédures générales

La procédure d'acquisition des données est incluse à la figure 4. Les sessions d'évaluation eurent lieu au département de physiothérapie de l'Institut de réadaptation de Montréal, lieu où se trouvait l'équipement du SOT. Chacun des enfants était évalué en une seule session d'une durée de 45 minutes. Pour éviter le biais d'expérimentateur, les enfants débutaient toujours par le test clinique (PCTSIB) avant l'évaluation instrumentée (SOT). Toutes les évaluations étaient effectuées par la chercheure principale qui connaissait les deux outils. La procédure est décrite en détail au sein de l'article 5.

TABLEAU 5: Description des conditions sensorielles testées avec les outils Pediatric Clinical Test of Sensory Interaction for Balance et Sensory Organization Test

Conditions	Principal système sensoriel ciblé	Procédure du PCTSIB	Procédure du SOT
1. Yeux ouverts	Systèmes tous disponibles	Yeux ouverts, debout sur un plancher plat	Yeux ouverts, debout sur plate-forme fixe
2. Yeux fermés	Proprioceptif + vestibulaire	Yeux fermés, debout sur un plancher plat	Yeux fermés, debout sur plate-forme fixe
3. Vision altérée	Proprioceptif + vestibulaire avec conflit visuel	Port du dôme avec les yeux ouverts, debout sur un plancher plat	Enceinte visuelle oscillant en phase avec les oscillations posturales, debout sur plate forme fixe
4. Yeux ouverts Support perturbé	Vision + vestibulaire	Yeux ouverts, debout sur la surface mousse (foam)	Yeux ouverts, debout sur plate-forme oscillant en phase avec les oscillations posturales
5. Yeux fermés Support perturbé	Vestibulaire	Yeux fermés, debout sur la surface mousse	Yeux fermés, debout sur plate-forme oscillant en phase avec les oscillations posturales
6. Vision altérée Support perturbé	Vestibulaire avec conflit visuel	Port du dôme avec les yeux ouverts, debout sur la surface mousse	Enceinte visuelle oscillant en phase avec les oscillations posturales, debout sur plate forme oscillant en phase avec les oscillations posturales

PCTSIB: Pediatric Clinical Test of Sensory Interaction for Balance; SOT: Sensory Organization Test of the Smart Balance Master™

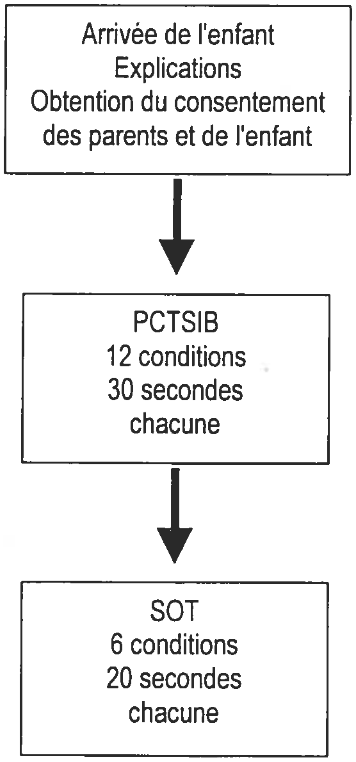


FIGURE 4: Procédure d'acquisition des données pour l'étude de comparaison entre le Sensory Organization Test (SOT) et le Pediatric Clinical Test of Sensory Interaction Test for Balance (PCTSIB)

<u>3.1.3 Présentation de l'article relatif à l'étude de comparaison entre deux outils d'évaluation de l'interaction sensorielle pour l'équilibre</u>

3.1.3.1 Problématique de l'article 5

Les outils d'évaluation des capacités d'interactions sensorielles dans le maintien de l'équilibre sont souvent utilisés dans le cadre d'évaluations cliniques et expérimentales. Les coûts élevés reliés à l'acquisition d'équipements commerciaux instrumentés (tels le Smart Balance Master™) destinés à cette évaluation ont contribué au développement d'un outil plus clinique visant les mêmes objectifs (Pediatric Clinical Test of Sensory Interaction for Balance). La question de l'équivalence réelle entre ces versions instrumentée et clinique n'a jamais été abordée. L'objectif principal de ce cinquième article était donc de comparer la performance d'enfants sans pathologie à l'aide de deux tests évaluant l'organisation sensorielle pour le maintien de l'équilibre; le Sensory

Organisation Test (SOT) du Smart Balance Master™, et le Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB) afin d'explorer la notion que l'outil clinique représentait une alternative à celui requérant de l'équipement plus sophistiqué et coûteux. L'hypothèse principale était que si le PCTSIB était une alternative clinique au SOT, les enfants devraient vraisemblablement y démontrer des performances fortement corrélées.

CHAPITRE 4
RÉSULTATS EXPÉRIMENTAUX

4.1 Résultats concernant les capacités d'équilibre suite au TCL

4.1.1 Article 1: Balance findings in a child before and after a mild head injury

Gagnon I, Friedman D, Swaine B, Forget R.. *Journal of Head Trauma Rehabilitation*; 2001; 16(6): 595-602.

This research was supported in the form of grants by:
Fondation Marie Robert pour la recherche sur les traumatisés crâniens, Réseau provincial de recherche en adaptation-réadaptation (REPAR), Ordre professionnel des physiothérapeutes du Québec and the Physiotherapy Foundation of Canada.
Gagnon I, Swaine B and Forget R receive bursaries and fellowships from the Fonds de la recherche en santé du Québec.

ABSTRACT

This case study reviewed the pre and post-injury balance performance of a child who had sustained a mild traumatic brain injury. A prospective design was used to document balance 5 days pre-injury, 1, 4 and 12 weeks post-injury. The assessments used were the balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency, the Pediatric Clinical Test of Sensory Interaction for Balance and the Postural Stress Test. One week after the trauma, balance deficits were observed in the three tests, improved 4 weeks after the injury and that performance remained stable over the following 2 months for two of the evaluations but that the Postural Stress Test performance failed to improve in the 3 month period following trauma. The good recovery of balance skills observed over the first month after injury seems to validate the current activity restrictions imposed on children after a mild traumatic brain injury. However, the persistence of poor performance in the area of reactions to external perturbations indicates that some deficits may persist beyond what is expected with this population. Keywords: Mild head injuries, balance

We wish to thank the child and her family for participation in the study.

Introduction

Mild head injuries (MHI) or concussions in children have been the subject of much interest in the last decade. However, researchers have been faced with many issues concerning the elaboration of studies concerned with the outcome of children after these injuries. The difficulties in establishing a clear diagnosis for the less severe cases, selection biases, the variability in medical management of the cases and the controversy regarding the presence and the duration of possible deficits are but a few of these concerns[1]

One cause for the difficulty in establishing the presence or absence of deficits is certainly the lack of adequate control of premorbid characteristics of these children, thus clouding the process of establishing the exact post-traumatic status. Pre-season evaluations are sometimes available for groups of elite athletes who will go on to be injured during the course of the season[2]. However, those do not reflect the substantial proportion of children who will sustain their injury during free play or less structured sport participation and for whom pre-injury data is impossible to obtain. As well, concerns have been raised about the predisposition of certain children to sustain mild head injuries, bringing on the importance of identifying and controlling for pre-injury characteristics[3-4].

This has lead to the persistence of a controversy regarding the presence of deficits as well as to many assumptions and possible misconceptions regarding the nature of the post-traumatic complaints especially those involved with subjective symptoms. The purpose of this case review is therefore to describe the pre-traumatic balance performance of an 11 year old girl who later sustained a MHI, and to describe her post-traumatic balance performance over the following 3 months.

Literature Review

Although head injuries vary in severity and recovery pattern, the majority of them are classified as mild. Mild head injury (MHI) is defined by the American Congress of Rehabilitation Medicine as a "traumatically induced physiological disruption of brain function manifested by at least one of the following: (1) any period of loss of consciousness (LOC), (2) any loss of memory for events immediately before or after the accident (post traumatic amnesia PTA), (3) any alteration in mental state at the time of the accident, and (4) focal neurological deficits that may or may not be transient[5]. A wide range of severity exists within the mild head injury category and this has lead to the development of a variety of classification systems generally identifying 3 grades of severity based on the duration of unconsciousness and post traumatic amnesia[6-7].

Various residual deficits related to MHI have been described, ranging from medical problems[8-10], including post-concussion syndrome and post-traumatic reaction[11-13], to cognitive and psychosocial deficits[14-19]. However, several studies report conflicting evidence as to the existence of these deficits, especially of motor deficits mostly due to methodological concerns that have been raised with many of these studies. Balance difficulties have been described by 2 groups in the adult population. Geurts et al.[20-21] measured balance using force platform posturography in 20 head injured subjects and compared them to 20 adults without injury. They found that after an average of 16 months post trauma, even though no subject presented with specific neurological deficits, the head injured subjects demonstrated a 50% increase in antero-posterior and lateral sway in quiet standing and that the loss of visual cues (eyes closed) affected them the most. Guskiewicz et al.[22] studied a sample of 22 head injured athletes and compared them to 11 non injured subjects using the Sensory Organization Test[23]. They found a postural instability present only in the initial 3 days post-trauma with a recuperation after that period. In both studies, neuropsychological testing revealed no deficits in the head injured individuals.

The only report focussing on the balance of children after a recent MHI is an exploratory study done by our group[24] where 28 children where assessed 2 weeks after a MHI using a standardized, norm referenced motor performance assessment, the Bruininks-Oseretsky Test of Motor Performance[25]. For the balance subtest, more than 40% of children presented with a decreased performance when compared to norms.

Unusual circumstances have made it possible to obtain pre-injury balance characteristics of one subject and the purpose of the present paper is to report on the pre and post traumatic balance skills of this 11 year old girl, in an attempt to provide evidence as to the existence of balance problems in some children after a very mild head injury.

Case Report

Subject

S.F. is an 11 year old girl who was initially seen before the injury as part of the testing on normal children in a protocol designed to study MTBI children prospectively. She is an above average student attending a bilingual school program and she participates in physical activities of various sorts on a regular basis. She sustained a MTBI while snowboarding 5 days after initial testing. After having given informed consent, she was recruited as a subject for the prospective study (ongoing) and was assessed 1, 4 and 12 weeks post injury according to the study protocol.

The MTBI she sustained was considered as a grade 1 concussion according to a standard classification system. She did not lose consciousness and had no documented PTA. She, however, had drowsiness, nausea and vomiting as well as headaches for a few hours post injury. She sought medical attention in the emergency department, and was subsequently admitted for overnight observation in the Pediatric and Adolescent Neurotrauma Program of the Montreal Children Hospital of the McGill University Health Center. She had a neurological screening evaluation prior to her release from the hospital and was considered not requiring any specific intervention from any rehabilitation services. She was given the usual discharge information including specific recommendations developed within the Pediatric and Adolescent Neurotrauma Program (annex 1) and was told to refrain from physical activities for a period of 4 weeks with subsequent gradual return to regular activities if completely symptom free for the last full week of this period of time. These guidelines were developed in the last 5 years to provide concrete information aimed at reducing post-concussion syndrome and the risk for a repeat head injury during the recovery period, potentially leading to more dramatic consequences (second impact syndrome).

Method

S.F. was assessed 5 days pre-injury, 1, 4 and 12 weeks post injury with 3 recognized and well established measures of balance for which psychometric properties are available: the balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), the Pediatric Clinical Test of Sensory Interaction for Balance (PCSITB)[26] and the Postural Stress Test (PST)[27]. The three measures assess different components of balance namely, dynamic balance in various conditions, interaction of the various sensory systems required for maintenance of balance and the ability to respond to backward perturbations when standing quietly. All assessment sessions were performed in her home and lasted approximately 45 minutes each. She did not require rest periods in the pre or post injury assessments. She had returned to school by the third day following her trauma and the only remarkable symptom persisting was a sense of fatigue and rare headaches. There was no reported obvious attention or concentration difficulties within the school setting.

Measures

The balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency is a measure of static and dynamic balance without external perturbations. It is part of a norm referenced test of global motor proficiency designed to discriminate between typically developing children and atypical development. The balance portion of this test comprises 8 items such as standing on one foot on the floor and on a balance beam and walking tandem in on a line or a balance beam.

The Pediatric clinical test of sensory interaction for balance evaluates a child's ability to use visual, somatosensory, and vestibular input for maintenance of standing balance. It was developed initially for adults by Shumway-Cook[28] to provide an inexpensive alternative to platform posturography. It assessed the duration of stance in 6 sensory conditions. In the P-CTSIB, tandem standing has been added and this version includes 12 conditions. Duration of standing is recorded until the child has maintained the position for 30 seconds or makes a postural adjustment defined by removing hands from hips, moving feet from the original position or falling requiring the examiner's help. The advantages of such a test reside in its ability to reflect the child's integration and use of diverse information in various conditions of static balance.

The Postural Stress test consists of a standard pulley system providing reproducible backward perturbations in a standardized manner, a factor that is often ignored or unstandardized in many measures of balance. It is used to test motor responses to external perturbations during "normal stance". The test evaluates the ability of the child to react and sustain upright posture in response to an increasing amount of weight dropped to produce a backward pull on a waist belt. The percentage of the child's body weight required to cause a stepping postural adjustment is recorded.

Results

The results of the 4 testing sessions are presented in table 1. The pre-injury assessment session took place 5 days prior to the injury and provides a baseline assessment for all evaluations. The balance subtest of the BOTMP, which has normative data, was well above the expected performance for her age group. The other tests were along the expected performance for a child her age.

At one week post injury, the three tests' performances were below the baseline. For the BOTMP, both raw score and and standard score performance were decreased (25-58%). Poor performance was observed for items concerned with the absence of visual input and stepping over an obstacle. With the PCSITB, some sensory conditions appear sensitive to the MHI effects. All reductions in performance occur in the reduced base of support condition (feet tandem), and when visual input is absent or conflicting (eyes closed or dome on head). Conditions when visual information is normal do not appear to pose difficulties. Finally, performance on the PST is decreased by 33% one week post trauma. The age equivalent performance, that was 29 months above her chronological age pre-injury, was reduced to 59 months below her chronological age one week post-injury.

Four and twelve weeks after trauma, the same tests were administered and globally found to have improved at 4 weeks and remained stable at 12 weeks. Performance on the BOTMP was back to age appropriate performance although remained around 7-21% below pre-injury performance, the only problem persisting being found with the eyes closed item. The PCSITB had returned to pre-injury values for all conditions but the PST's performance had remained as per the one week assessment, decreased by 33%. As for her age equivalent performance, it had improved to 14 and 17 months below her chronological age for the 4 and 12 week assessments respectively, a level considered within normal limits.

Discussion

The subject's pre-injury performance being above that expected for her age, we can safely assume that pre-injury balance problems were not present. Furthermore, her parents reported that she took gymnastics when she was younger and her performance was well above average, particularly on activities performed on the balance beam. She was tested with no knowledge that she would be a MTBI subject, thus eliminating possible biases on her performance. As well, no learning effect is observed in her performance as she would have been expected to perform better with time instead of demonstrating decreased performance on the tests. This allows for the guarded assumption that any post traumatic changes would be secondary to the MTBI.

The MTBI itself was considered to be at the very mild end of the MTBI spectrum. The absence of loss of consciousness and of post traumatic amnesia justifies its classification as a grade 1 concussion. Children who sustain such an injury receive attention or are brought to the emergency rooms only if post-concussion symptoms develop in the hours or days following the injury. They are generally considered not having any residual deficits after the resolution of the early symptoms, although significant controversy exists concerning this. The Pediatric and Adolescent Neurotrauma Program direction has felt very differently for the last decade having seen a variety of significant psychological and academic problems in children who sustained a MTBI and have not yet achieved their complete development.

Guidelines, based on arbitrary waiting periods post resolution of symptoms (such as headaches and nausea) or cognitive difficulties (such as confusion or memory problems), have been published concerning the return to sports for athletes having sustained a MHI[28,6-7]. These are aimed at providing an appropriate healing period for the injured brain, thus reducing the risk of re-injury and its possible dramatic consequences (Second Impact Syndrome). In the recommendations by the American Academy of Neurology (AAN), a child sustaining a grade 1 concussion can be allowed to return to physical activities after being asymptomatic for one week, illustrating the general consensus that no significant residual deficits are present. The neurological screening of S.F. was normal on release from the Hospital Neurotrauma Program and despite this, 7 days after the event, significant balance problems can be identified.

One could question whether the identified balance problems would in fact be attributed to distractibility or attention difficulties that have been reported in children post mild TBI. With high distractibility or attention difficulties, the child would have been expected to have some decreased balance in items where vision was allowed as this would have provided even more elements of distractions. On the contrary, S.F.'s difficulties were emphasized by the absence of vision, the variability of supporting surfaces or by the unexpected backward perturbations, further supporting the origin of her decreased performance arising from balance difficulties rather than attentional problems.

The significant resolution of deficits by the 4th week post-trauma is encouraging. This time marks the end of the strict restriction period in our institution regarding physical and strenuous activities (regardless of the grade attributed to the concussion) and the time at which children are allowed to gradually return to their regular activities, as tolerated and remaining symptom free (annex 1).

The fact that 2 out of 3 tests are back to or within 10% of the baseline performance could lead to the assumption that this return would be a safe one. As well it seems to support the length of time that these restrictions last. However, one has to question this in the light of the results of the 3rd test, the Postural Stress Test, where the child has to respond to quantified and standardized backward external perturbations while standing quietly and where the ability to sustain the perturbation without stepping backwards is measured. Many physical activities and sports involve external perturbations of all sorts and it is justified to question the functional significance and meaning of a reduced performance on that evaluation. A deficit could affect the ability to react appropriately, without excessive reliance on stepping reactions, and impair performance or be a risk for re-injury. Finally, performance at the 12 week assessment has remained stable when compared to the 4 weeks status. This lack of recovery to her pre-injury performance may be suggestive of residual and persisting balance problems requiring more than 3 months to resolve themselves.

In conclusion, this is one of the very few occurrence where quantitative pre-injury data has been available and standardized to use as a baseline to compare post injury performance of a child after a MTBI. The subject's performance on 3 balance measures was used to demonstrate the presence of early balance deficits post-injury as well as the evolution of the performance after one and three month. These findings could be viewed as support for the implementation of stricter or longer restriction periods for some children even after a very "minor" injury to allow for additional healing or adaptation to take place without placing the child at risk for re-injury, and thus support the orientation of the Pediatric and Adolescent Neurotrauma Program regarding recommendations. The assessment tools used also stress the fact that in order to identify balance problems, items such as single leg stance with eyes open or walking on lines may not be sufficient to identify deficits. Clinicians may have to include more specific assessments to ensure the completeness of their assessments and the validity of their judgements on the presence of deficits.

References

1.Kraus, J.F., McArthur, D.L., Silberman, T.A.: Epidemiology of mild brain injury. Seminars in Neurology 1994; 14: 1-7.

2.McCrea, M., Kelly, J.P., Kluge, J., Ackley, B., Randolph, C.: Standardized assessment of concussion in football players. Neurology 1997; 48: 586-588.

3.Matheny, A.P., Brown, A.M., Wilson, R.S.: Behavioral antecedents of accidental injuries in early childhood: A study of twins. The Journal of Pediatrics, 1971; 79: 122-124.

4.Bijur, P., Golding, J., Haslum, M., Kurzon, M. Behavioral Predictors of Injury in School age Children. American Journal of Disease in Children., 1988; 142: 1307-1312.

5.Mild Traumatic Brain Injury committee (American Congress of Rehabilitation Medecine, Head Injury Interdisciplinary Special Interest Group): Journal of Head Trauma Rehabilitation, 1993; 8: 86-87.

6.Cantu, R.C.: Head injuries in sport. British Journal of Sports Medicine 1996; 30: 289-296.

7.American Academy of Neurology. Report from the Quality Standards Subcommittee. Practice parameter: The management of concussion in sports (summary statement). Neurology. 1997; 48: 581-585.

8.Alexander, M.P., Mild traumatic brain injury: pathophysiology, natural history, and clinical management. Neurology, 1995; 45: 1253-60.

9.Parker, R. S., Rosenblum, A.: IQ loss and emotional dysfunctions after mild head injury incurred in a motor vehicle accident. Journal of Clinical Psychology, 1996; 52: 32-43.

10.Bijur P. E., Haslum, M., Golding, J. Cognitive and behavioral sequelae of mild head injury in children. Pediatrics 1990; 86: 337-344.

11.Szymanski, H. V., Linn, R.: A Review of the postconcussion syndrome. International Journal of Psychiatry in Medecine 1992; 22: 357-375.

12.Bohnen, N., Jolles, J., Neurobehavioral aspects of postconcussive symptoms after mild head injury, The Journal of Nervous and Mental Disease 1992; 180: 683-692.

13.Watson, M.R., Fenton, G.W., McClalland, R.J., Lumsden, J., Headley, M., Rutherford, H.: The post-concussional state: neurophysiological aspects. British Journal of Psychiatry. 1995; 167: 514-521.

14.Harvey, A.G., Bryant, R.A.: Acute stress disorder after mild traumatic injury. The Journal of Nervous and Mental Disease, 1998; 186: 333-337.

15.Lemmon, J., Keatley, M. A., Carnes, J., Acimovic, M. L., Josephs E., Purvis, J.: Mild traumatic brain injury, Psychological Factors and the Effects of the Medico-Legal System on Recovery. The Journal of Cognitive Rehabilitation 1995; september/october: 4-11.

16.Fay, G.C., Jaffe, K.M., Polissar, N.L., Liao, S., Martin, K.M., Shurtleff, H.A. et al: Mild pediatric brain injury: a cohort study. Archives of Physical Medicine and Rehabilitation, 1993; 74: 895-901.

17.Gulbrandsen, G.B.: Neuropsychological sequelae of light head injuries in older children 6 months after trauma. Journal of Clinical Neuropsychology, 1984; 6: 257-68.

18.Montgomery, E.A., fenton, G.W., McLelland, R.J., MacFlynn, G., Rutherford, W.H.: The psychobioloby of minor head injury. Psychological Medicine, 1991; 21: 375-384.

19.Segalowitz, S.J., Brown, D. : Mild head injury as a source of developmental disabilties. Journal of Learning Disabilities, 1991; 24: 551-59.

20.Geurts, A.C.H., Ribbers, G.M., Knoop, J.A., von Limbeek, J.: Identification of static and dynamic postural instability following traumatic brain injury. Archives of Physical Medicine and Rehabilitation, 1996; 77: 639-44.

21.Geurts, A.C.H., Knoop, J.A., Van Limbeek, J.: Is postural control associated with mental functioning in the persistent postconcussion syndrome. Archives of Physical Medicine and Rehabilitation 1999; 80: 144-149.

22.Guskiewicz, K.M., Riemann, B.L., Perrin, D.H., Nashner, L.M.: Alternative approaches to the assessment of mild head injury in athletes. Medicine and Science in Sports and Exercise, 1997; 29: s213-221.

23.Forssberg, H., Nashner, L.M. Ontogenic development of postural control in man: adaptation to altered support and visual conditions during stance. Journal of Neuroscience. 1982; 2: 545-552.

24.Gagnon, I., Forget, R., Friedman, D., Sullivan, S.J.: Motor performance following a mild traumatic brain injury in children: an exploratory study. Brain Injury 1998; 12: 843-853.

25.Bruininks, R.H.: The Bruininks-Oseretsky Test of Motor Performance, Circle Pines, MN, American guidance service, 1978.

26.Crowe, T.K., Deitz, J.C., Richardson, p.K., Atwater, S.W.: Interrater reliability of the pediatric clinical test of sensory interaction for balance. Physical and Occupational Therapy in Pediatrics 1990; 10: 1-27.

27.Wolfson, L.I., Whipple, R., Amerman, P: Stressing the postural response: a quantitative method for testing balance. Journal of the American geriatric Society 1986; 34: 845-850.

28.Shumway-Cook, A., Horak, F.B.: Assessing the influence of sensory Interaction on balance. Physical Therapy 1986; 66: 1548-1550.

29.Kelly, J.P., Nichols, J.s., Filley, C.M., Lillehei, k.O., Rubinstein, D., Kleinschmidt-DeMasters, B.K.: Concussion in sports; guidelines for the prevention of catastrophic outcome. Journal of the American Medical Association 1991; 266: 2867-2869.

Table 1: Balance scores

Test		Pre-injury	1 week post injury		4 weeks post-injury		12 weeks post injury	
		Score	Score	Δ %*	Score	Δ %*	Score	Δ %*
BOTMP	RS	28	21	-25%	26	-7%	26	-7%
	SS	19	8	-58%	16	-16%	15	-21%
PCSITB	**FTo**							
	Eo fl	30s	30s	0	30s	0	30s	0
	Eo fo	30s	30s	0	30s	0	30s	0
	Ec fl	30s	30s	0	30s	0	30s	0
	Ec fo	30s	30s	0	30s	0	30s	0
	Do fl	30s	30s	0	30s	0	30s	0
	Do fo	30s	30s	0	30s	0	30s	0
	FTa							
	Eo fl	30s	30s	0	30s	0	30s	0
	Eo fo	30s	30s	0	30s	0	30s	0
	Ec fl	30s	6.2s	-79%	30s	0	30s	0
	Ec fo	30s	10.1s	-66%	30s	0	30s	0
	Do fl	30s	30s	0	30s	0	30s	0
	Do fo	30s	15.1s	-50%	30s	0	30s	0
PST	%BW	6	4	-33%	4	-33%	4	-33%

BOTMP: Bruininks-Oseretsky Test of Motor Proficiency, PST: Postural Stress Test, PCSITB: Pediatric Clinical Sensory Interaction Test for Balance, RS: raw score, SS: standard score, AP: deviation in months of performance away from chronological age, Fto: feet together, Fta: feet tandem Eo: eyes open, Ec: eyes closed, Do: dome (sway referenced vision), fl: floor (standing on the floor), fo: foam (standing on foam), %BW: % body weight required to elicit a backward step in response to the perturbation.

*: (Δ %) % difference from between pre and post-injury score

Annex 1

The Montreal Children's Hospital
Pediatric & Adolescent Neurotrauma Program

Recommendations for activity restrictions

☐ 1 week **☐ 2 weeks** **☐ 4 weeks** **☐__ weeks**

The following restrictions are important to allow for an adequate healing period, and reduce the chance of having another head injury during this time. The restrictions should help in reducing persistent post head injury headache, dizziness, visual disturbances, poor attention span, excessive fatigue, and in some cases seizures.

For children of all ages

- Inform the teachers, and coaches of the head injury & restrictions
- No gym, contact sports, and other strenuous activities
- Adequate rest and breaks are encouraged
- A gradual return to school (half days for the 1st week) or short term modification of the workload may be indicated if symptoms persist
- Supervision in the classroom and on the playground at recess & lunch
- Limit time spent on video games, computers, and television as these activities may provoke increased headaches
- Avoid movies in large screen theatres as the lights & sounds may be overwhelming
- Supervised swimming is permitted but no diving or jumping into the water
- When returning to sports & recreational activities REMEMBER to wear appropriate protective head gear and equipment at all times!
- Following the period of restriction the return to physical activity should be done gradually
- You should be completely free of symptoms for the entire last week of the restricted period before returning to all activities.

Additional recommendations for adolescents

- Absolutely no drugs or alcohol
- Avoid frequenting bars/pubs due to the excessive amount of noise, lights, smoke, etc. which again may provoke headaches
- Other specific restrictions include______________________

4.1.2 Article 2: Children demonstrate decreased dynamic balance following a mild traumatic brain injury

Gagnon I, Swaine B, Friedman D, Forget R. *Archives of Physical Medicine and Rehabilitation* . Accepté pour publication

This research was supported in the form of grants by:
Fondation Marie Robert pour la recherche sur les traumatisés crâniens, Réseau provincial de recherche en adaptation-réadaptation (REPAR), Ordre professionnel des physiothérapeutes du Québec and the Physiotherapy Foundation of Canada. Gagnon I, Swaine B and Forget R receive bursaries and fellowships from the Fonds de la recherche en santé du Québec.

Part of this manuscript was presented at the 3rd World congress of Neurorehabilitation, Venice, Italy, 2-6 April 2002 and the abstract published in Neurorehabilitation and Neural Repair 2002; 16: 22-3.

Abstract

Objective: Compare the balance skills of children after a mild traumatic brain injury (mTBI) with that of non-injured children matched for age, sex, and pre-morbid level of physical activity. **Design**: Cohort study. **Setting:** Pediatric trauma center **Participants:** 38 children aged 7 to 16 yrs (12.2±2.8) were recruited in each group. Children with mTBI had a mean Glasgow Coma Scale score (GCS) of 14.8, and were considered normal on a neurological assessment at hospital discharge. Non-injured children were friends of those with mTBI. **Intervention:** Assessments of balance were conducted at 1, 4, and 12 weeks post-mTBI and at corresponding time intervals for the controls. **Main Outcome Measures:** The Balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), the Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB), and the Postural Stress Test (PST) were used. **Results:** Over the time interval of the study, ANOVAs revealed that children with mTBI performed significantly worse than the non-injured group on the balance subtest of the BOTMP ($p<0.001$) and on the PST ($p=0.031$), as well as on the eyes closed conditions in the tandem position of the PCTSIB ($p=0.05$). **Conclusion:** Children with a mTBI still demonstrated balance deficits at 12 weeks post-injury. As such, these deficits should be taken into consideration when planning a return to physical activities, particularly to those requiring subtle balance skills.

Keywords:

Brain injuries, pediatrics, equilibrium

Introduction

Balance is frequently reported as affected after a moderate or severe traumatic brain injury (TBI)[1]. In contrast, information about the balance of individuals who sustain a mild TBI (mTBI) is scarce, especially in children. Recent reports, however, have shown that balance problems can occur among children following a mTBI[2-4]. This suggests that it may be important to assess children's balance following mTBI to ensure a safe return to sports and other demanding activities.

Balance can be defined as a condition where all forces and torques acting on the body are in equilibrium so that the individual's centre of mass is within the individual's limits of stability[5-8]. Postural control is the means by which balance is achieved with the purpose of controlling the relation between the center of mass and the individual's base of support. To maintain a position or to ensure appropriate transitions between positions, the nervous system must integrate rapidly incoming sensory information from various sources (visual, vestibular, proprioceptive), and use this information to generate complex motor responses. Thus, individuals exert their postural control using specific, but highly adaptable, sequences of muscle activation that are described as ankle, hip, and stepping strategies. These responses can be accomplished in a predictive mode (anticipatory control) or in a reactive mode (feedback control) or by a combination of both of these elements[5] and are adjusted in their sequence, direction, and amplitude to the context of the situation or perturbation. Perturbations that threaten balance may be internal when associated with voluntary movements and produced by one's own body, or external if induced by a changing environment.. Maintaining one's balance is a complex task, subject to the maturation and development of the systems involved[5,9]. Good balance is necessary for many activities of daily living and becomes even more essential when performing demanding physical activities where the relation of the center of mass to the limits of stability is constantly being challenged.

Up to 80% of individuals sustaining severe TBI present with some balance deficits in the standing position[1,10-11]. Focal primary brain damage can lead to specific motor deficits hindering balance (e.g. abnormal muscle tone) or affect single sensory systems[12-14]. However, it is the extensive and diffuse nature of the axonal injury that is regarded as responsible for the balance deficits observed following severe TBI[15]. Diffuse damage is thought to contribute to the disruption of mechanisms responsible for the appropriate sensory-motor integration required for the maintenance of balance. Work by Shumway-Cook[12] suggests that individuals with severe TBI have sensory integration problems. These are demonstrated by an increase in postural sway in conditions of reduced or conflictual sensory inputs.

Because individuals with mTBI do not typically present with the detectable neurological deficits seen following severe TBI, the investigation of balance following a mTBI had, until recently, been largely neglected in the literature. Individuals who have sustained a mTBI are thought to suffer mostly from cognitive as opposed to motor problems[16-18]. In the last decade however, interest in persons sustaining a mTBI has increased, and a number of research teams have identified balance problems even after mTBI.

Guskiewicz and colleagues[19-20] examined the balance and the cognitive performance of 11 collegiate athletes one, three, five and ten days after they had sustained a mTBI. They found that mTBI athletes did not differ from a matched control group of non-injured athletes on the cognitive performance assessments, but performed significantly poorer than the control group on the Sensory Organization Test of the Neurocom Smart Balance Master System™ up until the third day. These latter findings were attributed to sensory interaction problems, because the individuals "fail(ed) to use their visual system effectively" and were unable to resolve sensory conflicts. Geurts and colleagues[21] reported a significant increase in postural sway in quiet standing and decreased weight shifting speed during a dynamic balance task in a group of individuals with TBI (most of whom had sustained a mTBI) as compared to healthy controls at six months post-trauma. The addition of an arithmetic task did not alter the balance performance of the mTBI group any more than it did for the control group. These findings were instrumental in the recognition that balance problems can be present even after a mTBI and as long as six months post-injury, in the absence of documented neurological deficits. More recently, Geurts et al.[22] found that static and dynamic instability in mTBI subjects was moderately associated to cognitive performance assessed using the Symbol-Digit Substitution Test of the Weschsler Adult Intelligence Scale (testing attention and mental speed). However, no association between the postural problems and emotional well-being as measured by the Symptom checklist–90 was found. Because both the cognitive performance and the balance problems were found to be related to an increased information processing time, the authors suggested the existence of an organic cause for these difficulties, as opposed to one of a more functional emotional nature. Despite the substantial contribution of Geurts's work, it is important to note that the subjects investigated had motor complaints such as "gross motor clumsiness" months after the mTBI and therefore the results therefore cannot be generalized to the whole mTBI population. In conclusion, the work of the last two research groups demonstrated varying degrees of balance difficulties following mTBI in adult populations. To our knowledge, similar work has never been reported among pediatric and adolescent populations.

Very few reports exist on the assessment of balance in children after a mTBI. Moreover, reports have rarely focused specifically on balance, choosing instead to address motor performance as a whole. For example, work by Fay et al.[23] concluded that motor problems did not exist following mTBI based on data collected using questionnaires administered to parents of 53 children with mTBI and 53 matched healthy controls at three weeks and one year post-trauma. Although this type of questionnaire to assess motor performance is justifiable in the context of studies examining multiple domains (motor, cognitive, social, academic), it lacks the specificity of direct observation of motor performance that is essential to the identification of subtle motor deficits such as balance problems. Our group documented motor performance (including balance) in children after a mTBI using a clinical standardized test, the Bruininks-Oseretsky Test of Motor Proficiency and found that up to 40% of the injured children had decreased balance performance when compared to published norms[2]. The absence of a control group and the lack of clarification as to which aspects of balance were affected limit somewhat the interpretation of the findings. A recent case study reporting on the balance performance of a 11 year old girl before and after a mTBI, using three clinical assessments, revealed that some aspects of balance, including responses to external perturbations, persisted even three months after the injury[3]. Finally, preliminary results from the present study revealed that the children did in fact present balance deficits when compared to a control group at 1 and 4 weeks post-injury[4]. In conclusion, it remains unclear whether children present with balance problems following mTBI and if so, how long the problems persist. Clearly these questions are clinically important in the context of developing intervention strategies and of safely returning children to physical activities where balance could be challenged following mTBI.

In order to address the limitations of the previously reviewed research regarding balance in children after a mTBI, the purposes of the present study were to 1) determine whether children having sustained a mTBI present with balance deficits when compared to a group of non-injured children matched for age, sex and premorbid level of physical activity and 2) describe the evolution of recovery of different aspects of balance during the first three months following the injury.

Methods

Subjects

Forty children, aged 7 to 16 years, having sustained a mTBI agreed to participate in this study. A mTBI is defined by the American Congress of Rehabilitation Medicine[24] as including at least one of the following criteria; any period of loss of consciousness of 30 minutes or less, any loss of memory for events immediately before or after the accident lasting less than 24 hours, or a Glasgow Coma Score of 13-15, 30 minutes after the injury. The children were recruited from consecutive admissions to the Pediatric and Adolescent Trauma Program of the Montreal Children's Hospital, McGill University Health Center in Montreal, Canada. Criteria for such admissions include nausea, vomiting, drowsiness, headaches or any loss of consciousness. All children were considered normal on a standard neurological exam performed just prior to discharge from the hospital (usual stay of a few hours to an overnight stay). Children were excluded if they presented a pre-traumatic condition affecting the evaluation of balance (e.g. vestibular problems), a documented medical diagnosis of learning or attention deficit disorder as well as regular use of Ritalin, attendance to a special school for learning or behavioral problems, and fractures or co-morbidities limiting the assessment of balance. Similar exclusion criteria were applied to a sample of 40 control children recruited among the friends of the mTBI children and matched for age, sex, and pre-morbid level of physical activity. By choosing friends of the injured children, were able to control for potential and unidentifiable confounders. Pre-morbid level of physical activity was established using the Activity Rating Scale, a single 5-level question designed to establish level of participation in physical activities in large epidemiological surveys[25].

Two children in the mTBI group only completed the initial evaluation; one moved out of the region and the other decided not to continue to participate for personal reasons. Their matched control child was therefore removed from the data analysis to ensure similarity between the groups.

The characteristics of the mTBI group, presented in table 1, are consistent with those reported in the literature with boys representing 2/3 of the sample, falls being the most frequent etiology and headaches and nausea-vomiting being the most frequent initial symptoms present. The high average admission GCS illustrates the very mild nature of the TBI that was sustained by the children. Sixty-five percent of the children sustained a mTBI that could be classified as a grade 2 concussion and 35 percent sustained a grade 3 concussion as per the American Academy of Neurology practice parameters[26]. On a clinical note, forty two percent of the sample presented with a posterior site of impact as documented in the child's medical chart. This information is rarely documented in research studies, but thought to be of some significance by many clinicians due to the anatomical location of a certain number of structures involved in postural control such as the visual cortex. The mTBI children described themselves as slightly more active than children of their own age and sex (Activity Rating Scale 3.5±0.9) and the control children were matched accordingly (Activity Rating Scale 3.5±0.8).

Measures

Three assessment tools were administered to both mTBI and non-injured children; the Balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP)[27], the Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB)[28-29] and the Postural Stress Test (PST)[30]. These measures were chosen because they purport to assess different components of balance namely, static and dynamic balance in various conditions, interaction of the various sensory systems required for maintenance of balance, and the ability to respond to backward perturbations in quiet standing. The three measures including their psychometric properties are presented in table 2.

The balance subtest of the BOTMP is a functional measure of static and dynamic balance without external perturbations. It therefore focuses primarily on the assessment of the child's anticipatory postural control. It is part of a norm-referenced test of global motor proficiency designed to discriminate between typically developing children and those presenting with atypical development. The balance portion of this test comprises eight items such as standing on one foot on the floor or on a balance beam and walking in tandem on a line or a balance beam.

The PCTSIB evaluates a child's ability to use visual, somatosensory, and vestibular input for maintenance of standing balance. It was developed initially for adults by Shumway-Cook[31] to provide an inexpensive alternative to platform posturography and assess the duration of stance in six sensory conditions. In the adapted pediatric version[28], tandem standing has been added to include 12 conditions. In the present study, single leg stance was added to ensure enough variability between the children. Duration of standing is recorded until the child has maintained the position for a maximum of 30 seconds or alternately until the child makes a postural adjustment defined by removing hands from hips, moving feet from the original position, or falling requiring the examiner's help. This test reflects the child's ability to integrate and use diverse information to react to various perturbing conditions in static balance.

The PST consists of a standard pulley system providing reproducible external perturbations in a standardized manner. Specifically, the test evaluates the ability of the child to react and sustain upright posture in response to an increasing amount of weight dropped to produce a backward pull on a waist belt. The amount of weight required to cause a stepping postural adjustment is recorded in terms of its percentage of the child's body weight.

In addition to the balance measures, information regarding the injury was obtained from the child's medical file. The Rivermead Post-Concussion Symptoms Questionnaire[32-33] was also administered at every assessment in order to document the presence and severity of 16 commonly experienced symptoms following mTBI such as nausea and headaches.

Procedure

Children who met inclusion criteria and their parents were met to explain the study on the day of their admission to the trauma program. Those interested in participating were met on the same day by the study coordinator and initial questionnaires, concerning the pre-morbid physical activity level and sociodemographic information, were completed. Children were then assessed at three different times: during the first week, and then again at four and twelve weeks post-injury. Children in the control group were assessed at corresponding time intervals. The assessment times were chosen because of their importance in the child's recovery. For example, the fourth week marks the end of an activity restriction period imposed on the child[34] and 12 weeks is the time when most post-concussion symptoms are typically resolved[35]. The evaluations were completed by an experienced pediatric physical therapist who, to the best of our ability and for most of the children, was blind to group status. The evaluator had been trained in the standardized administration of all the measures and her performance was verified several times over the data collection period. Moreover she used two of the three tools in her practice making her very proficient in their administration. All evaluations took place in the children's homes to minimize travelling inconvenience and school absenteeism. Tests were first explained to the child and a practice trial was permitted to allow familiarization with the procedure. The study received both scientific and ethical approval from the institutional review board of the Montreal Children's Hospital, McGill University Health Center. All children and their parents signed informed consent forms prior to data collection.

Data Analysis

The following scores were computed for each child: the BOTMP-balance raw score (computed from individual performance on eight items for a maximum of 32 points), balance subtest age equivalent scores (derived from sub-test raw scores and expressed as number of months above or below chronological age), the duration (seconds) of stance in each PCTSIB condition, and the percentage of body weight required to cause a stepping postural adjustment in the PST. Group descriptive statistics were compiled.

To address the study objectives, the test performances of the mTBI children were compared to those of the children in the control group using two-way ANOVAs (group and time) with repeated measures on the time factor. Greenhouse Geiser corrections were used for all ANOVA results when the distribution of the variables departed from normality. Differences between groups at each assessment time were determined using independent t-tests with Bonferroni correction and the time effect for each group was determined using one-way ANOVA for repeated measures with Bonferroni correction for contrasts. When some assumptions for the use of parametric tests were violated, non-parametric tests were also performed to verify the validity of the results. As statistical results were similar, only those obtained with the parametric statistical tests are presented here. In an attempt to identify subgroups of children presenting with the most significant deficits, the relations between the injury variables (GCS, site of impact, concussion grade, age at injury, initial symptoms) and the injured children's performances on each of the balance tests were examined using chi-square analysis or Spearman rank order correlations when appropriate. As well, at each assessment time, the relation between the post-concussion symptoms and the children's performances on each of the balance tests was explored using Spearman rank order correlations. Finally, to verify the stability of the tests over time, intra-class correlation coefficients (ICC) were obtained for the control group between the first and second testing times (3-week interval) for all variables. These ICCs varied between 0.50 (PCTSIB in single leg stance on the foam with eyes open) and 0.95 (BOTMP age equivalent score), showing that the tests have acceptable test-retest reliability. The SPSS statistical package, version 10.0, was used for all statistical analyses[36].

Results

The descriptive statistics for both groups and for all tests are presented in table 3. The results of the BOTMP raw scores and BOTMP age equivalent scores are presented in figures 1 and 2. The ANOVA performed on the BOTMP raw score revealed that there were significant differences between the groups across all testing sessions (F=16.92; p<0.001). There was a main effect for the time factor (repeated measure) (F=13.12; p<0.001). A group x time interaction was found for the performances of the injured and non-injured children (F=3.25; p=0.043). This interaction reflects how the groups' performances changed differently over time as described below. The mHI children performed worse than those non-injured at 1 week (t=-4.72; p=0.001), 4 weeks (t=-3.29; p=0.002) and 12 weeks post-injury (t=-2.33; p=0.02). When the groups were taken separately, the time effect was present for the mHI group (F=9.37; p<0.001) and for the non-injured group (F=4.54; p=0.024). The injured children presented with lower scores in the first week when compared to those of the 12th week (p=0.009), while the non-injured children improved their performance between the 4th and 12th weeks (p=0.031).

For the BOTMP age equivalent scores, there was a between group effect (mHI vs controls) (F=15.89; p<0.001). There was a main effect for the time factor (repeated measure) (F=8.42; p<0.001), but there was no group x time interaction for the performances of the injured and non-injured children (F=2.33; p=0.104). Specifically, the mHI children performed worse than the control group at week 1 (t=-4.36; p<0.001), week 4 (t=-3.34; p=0.001) and week 12 (t=-2.76; p=0.007). Only the performances of the mHI group were found to change over time (F=6.51; p=0.003) where the children had a better performance at week 12 compared to week 1 (p=0.003). The performance of the children on some individual items of the BOTMP balance subtest was also found to be different between the two groups. These include item 3, single leg stance on the beam with eyes closed (F=6.90; p=0.011), item 7, heel-toe gait on the beam (F=10.84; p=0.002) and item 8, stepping over an obstacle on the beam (F=11.48; p=0.001).

For the PCTSIB, descriptive statistics showed that for both groups, single leg stance was more difficult and resulted in more variability than tandem stance. Children with mTBI performed worse than children in the control group only in the eyes closed conditions in tandem position when standing on the floor (F=4.12; p=0.046) and when standing on the foam (F=3.99; p=0.049). Children in both groups performed in a similar manner for all other conditions of the PCTSIB (p varied between 0.114 and 0.740) (not shown).

Figure 3 illustrates the results of the PST. The ANOVA performed on the PST results detected differences between injured and non-injured children (F=4.83; p=.031) for the testing period. However, when the assessment times were examined individually, only a trend could be observed for the assessments at 1 week (t=-2.26; p=0.027) and 12 weeks (t=-2.31; p=0.024) where the injured children performed worse than the non-injured children. There was a main effect for the time factor (repeated measure) (F=20.11; p<0.001), but there was no group x time interaction for the performances of the injured and non-injured children (F=1.14; p=0.32). When the groups were taken separately, the time effect was present for the mHI group (F=17.88; p<0.001) and for the non-injured group (F=12.95; p<0.001). The injured children presented with lower scores in the 1st week when compared to those of the 4th week (p<0.001) and to those of the 12th week (p<0.001). The non-injured children also improved their performance between the 1st and 4th weeks (p=0.043) and 4th and 12th weeks (p<0.001), perhaps indicating a learning effect for this test.

As for post-concussion symptoms (figure 4), there was a strong between group effect across all testing sessions ($F=20.11$; $p<0.001$) with the mHI children reporting a significantly greater number of symptoms than the control group at all testing times. There was a main effect for the time factor ($F=23.41$; $p<0.001$) (repeated measure) and there was a group x time interaction ($F=10.79$; $p<0.001$) for the performances of both groups. Specifically, the time effect was strong for the mHI group ($F=20.59$; $p<0.001$) and children improved between weeks 1 and 4 ($p=0.002$) and between weeks 4 and 12 ($p=0.002$). On the other hand, the time effect just reached significance for the control group ($F=3.35$; $p=0.04$).

There was no significant relation between the number of post-concussion symptoms and the balance test scores except for the BOTMP age equivalent score ($r^2=-0.40$; $p=0.01$) at the 1 week assessment. Analysis of mTBI subgroups revealed that only the grade of the concussion (2 vs 3) was able to differentiate among the performances of the injured children, and this was only for the BOTMP age equivalent age score (cut off score of 24 months below chronological age) at 1 week ($X^2=4.06$; $p=0.04$) and 4 weeks ($X^2=4.87$; $p=0.027$) post-injury.

Discussion

The overall findings of this study suggest that, despite a normal neurological examination and a lack of apparent motor problems at the time of hospital discharge, a significant number of children having sustained a mTBI present with some form of postural instability during the first three months following the injury. Though the deficits attenuated over the three-month period, they remained present at the end of the assessment period. The nature of the deficits identified contribute useful information for developing hypotheses regarding the mode of postural control (anticipatory vs reactive) or systems that may be affected following a mTBI.

Children with mTBI did not perform as well as their non-injured friends on the balance subtest of the BOTMP, confirming the results obtained in an earlier exploratory study[2]. Three items are responsible for the differences in performance found between the groups. Although all involve activities performed on the balance beam, it appears that the combination of the narrow base of support with an absence of vision (one item) or with tasks involving higher levels of motor coordination (two items) is likely responsible for these deficits. The hypothesis regarding the former combination (narrow base of support + absence of vision) is supported by the findings that simply narrowing the base of support, while allowing the use of vision (as tested in another item of the BOTMP), was unable to differentiate between the two groups. Similarly, the task of standing on one foot with eyes closed on the floor (one item of the PCTSIB and the Romberg Test[26]) did not differentiate between the groups. The idea behind the latter combination (narrow base of support + high level motor coordination) is supported by the findings that the performance on other BOTMP items assessing the components in isolation (walking freely on balance beam, or walking heel-toe on the floor) were found not to differentiate between the groups.

The performance of mTBI children was poorer than that of control children on the BOTMP tasks demanding more refined postural control and higher levels of anticipatory postural control. Anticipatory postural adjustments have been postulated as being programs executed independently from feedback control[37-40]. Sensory feedback would, however, be necessary to learn new anticipatory postural adjustments[41]. The deficits observed in mTBI children could indicate that they have problems with the anticipatory control involved in preparing for and organizing challenging balance tasks. It is difficult to know from our results, however, whether the impairments reside in retrieving appropriate anticipatory control programs or if they are related to an inability to adapt the program to a new situation. Future studies, where EMG activity would be recorded while children performed these tasks, could help determine whether the timing and choice of muscle activity prior to movement execution are in fact different in children after a mTBI as compared to a control group. Moreover, a systematic EMG recording during several trials would help determine if learning occurs and if adaptation strategies are developed.

The children were also assessed with two tests examining their responses to various perturbations. In the PCTSIB, only the tandem stance eyes closed on the floor (theoretically providing a greater challenge to the proprioceptive system) and on the foam (challenging the vestibular system) were able to detect difficulties after the mTBI. These findings provide some support for the existence of problems in the integration of available sensory information in the control of balance following mTBI and indicate an inability to efficiently use proprioceptive and vestibular information in the absence of vision. This evidence is reinforced by the results of the static balance task of the BOTMP (eyes closed on balance beam), also sensitive to the absence of visual information and to inappropriate use of proprioceptive and vestibular sensory information. We were unable to replicate the findings reported by Guskiewicz and this may be explained by the fact that the instrument used in our study (e.g. the PCTSIB) differed from the one used by Guskiewicz (e.g. the Smart Balance Master™). Indeed, these two tests probably measure different aspects of balance as suggested in a pilot study comparing a group of normal children on these two tests (Gagnon et al. unpublished results).

The Postural Stress Test, on the other hand, is analogous to the pushing and pulling motions involved in many sports and physical activities. Surprisingly, reports on children's ability to react to these perturbations could not be found in the literature, even after severe TBI. Children in the control group, like young healthy adults[42], were able to sustain 5% of their body weight before making a stepping postural adjustment. The mTBI children in our sample were found to sustain less than 5% of their body weight at the initial evaluation, replicating a similar trend observed with adults post-CVA[43]. Both groups improved over the three-month assessment period and a learning effect is most likely present for this test. Nevertheless, the performance of mTBI children tended to remain poorer than that of the non-injured children and difficulties related to feedback control cannot be ruled out. However, even if feedback sensory control is crucial when responding to external perturbations, anticipatory control deficits could affect the PST results. Indeed, externally controlled perturbations likely involve some anticipatory control to prepare for the perturbation itself especially if, as was the case in our study, the children are familiar with the activity (practice trial).

Based on these findings, it may be appropriate to evaluate a child's balance after a mTBI particularly if combinations of the following components of dynamic and static balance are included in the assessment. First, complex dynamic balance tasks (such as avoiding obstacles), performed on a narrow base of support (such as a balance beam) should be included. Moreover the test should also address the ability to maintain static standing balance on narrow or unstable bases of support in the absence of vision, or while reacting to standardized externally controlled perturbations. Evidence from our study supports the notion that these components should not be evaluated in isolation as this may result in an inability to detect the subtle but important changes present after the mTBI.

Finally, the observed deficits may also point to problems with the visuo-motor control required in the specific motor tasks themselves (placing the feet heel to toe or stepping over an obstacle). This, however, is unlikely since earlier work[2] revealed better than expected skills in the visuo-motor control subtest of the BOTMP for more than 60% of the children tested. Attentional or information processing difficulties have been reported in individuals following a mTBI [17,44-46], and the balance problems identified in our study could be related to specific problems of attention rather than to actual balance. In fact, attention and mental speed have been shown to be related to balance in adults after a mTBI[22]. The presence of decreased attention among children with mTBI remains controversial, as shown in a review of 40 studies (1970-1995) of the neuropsychological outcome of children after a mTBI[18]. In this review, studies found to be the most methodologically sound failed to demonstrate any cognitive problems, including attention or information processing problems, subsequent to a mTBI. In addition, Geurts[21] and Guskiewicz's[19] research teams, who both administered neuropsychological assessments and postural stability assessments, did not find specific attentional problems in individuals presenting with postural instability when compared to controls.

Attempts to find relationships between subgroups of mTBI children and balance performance failed for most variables. The degree of severity of the mTBI in terms of concussion grades was the only criteria by which the performance on the BOTMP age equivalent at one and four weeks was different. Children having sustained a grade 3 concussion performed significantly worse than those having sustained a grade 2 concussion, where the main difference between grades is the presence of any type of loss of consciousness at the time of injury. Concussion grade might therefore be a useful indicator of balance outcome following mTBI among children of this age group.

Although the present study sheds some light on the early balance outcome of children following a mTBI, a longer follow-up period would be necessary to document the resolution or persistence of balance difficulties following the injury. As well, increasing the sample size may have improved the power of the statistical analysis to detect differences between groups on certain measures. The use of assessment tools that had, up until now, been used exclusively with adults (PST, Rivermead PCS questionnaire) may be an additional limit to our study. However, our study also demonstrates the feasibility of using these measures with a pediatric population. Their use could contribute to the standardization of clinical evaluations with children after a mTBI.

In conclusion, postural instability was found up to three months following mTBI in children, despite normal neurological examinations. This deficit was particularly evident during the performance of tasks requiring 1) control over a narrow base of support, 2) use of proprioceptive and vestibular information and 3) responses to perturbations. These results have implications with regards to when and whether these children can safely resume their previous activities. Children with mTBI are typically permitted to return to their regular physical activities during the initial month following the injury (depending on the grade of the concussion they sustain[34]) providing the post-concussion symptoms have resolved. Such protocols are designed to diminish the risk for re-injury. Because the recovery of postural instability was shown to take longer than four weeks for some children, it is possible that these children may have been at risk of re-injury. We did not assess the children's performance during their physical activities and therefore are unable to confirm this hypothesis. At the very least, identification of the deficits would allow families to be forewarned about possible balance problems. Although children may return to their activities once symptoms have resolved, the results suggest that more demanding activities requiring subtle balance skills should be avoided during the first three months post-injury.

AKNOWLEDGMENTS

The authors wish to acknowledge the financial support of the Fondation Marie Robert pour la recherche sur les traumatisés crâniens, Réseau provincial de recherche en adaptation-réadaptation (REPAR), Ordre professionnel des physiothérapeutes du Québec and the Physiotherapy Foundation of Canada.

We also wish to thank the children and their families for their participation in this research.

REFERENCES

1. Wade LD, Canning CG, Fowler V, Felmingham KL, Baguley IJ. Changes in postural sway and performance of functional tasks during rehabilitation after traumatic brain injury. Arch Phys Med Rehabil 1997; 78: 1107-11.

2. Gagnon I, Forget R, Sullivan SJ, Friedman D. Motor performance following a mild traumatic brain injury in children: an exploratory study. Brain Injury 1998; 12: 843-853.

3. Gagnon I, Friedman D, Swaine B, Forget R. Balance findings in a child before and after a mild head injury. Journal of Head Trauma Rehabilitation 2001; 16: 595-602.

4. Gagnon I, Forget R, Swaine B, Friedman D. Balance findings after a mild head injury in children. 3rd World congress of Neurorehabilitation, Venise, Italie, 2-6 avril 2002, Neurorehabilitation and Neural Repair. 2002; 16: 22-23.

5. Horak FB. Clinical measurement of postural control in adults. Physical Therapy 1987; 67: 1881-1884.

6. Reed ES. Changing theories of postural development. In Woollacott, M.H., Shumway-Cook, A. (eds). Development of posture and gait across the life span, Columbia SC: University of South Carolina Press, 1989.

7. Woollacott MH, Shumway-Cook A. Concepts and methods for assessing postural instability. Journal of Aging and Physical Activity 1996; 4: 214-233.

8. Horak FB, Henry SM, Shumway-Cook A. Postural perturbation, new insights for the treatment of balance disorders. Physical Therapy 1997; 77: 517-533.

9. Horak FB, Nashner LM. Central programming of postural movements: adaptation to altered support surface configurations. Journal of Neurophysiology 1986; 55: 1369-1381.

10. Chaplin D, Deitz J, Jaffe KM. Motor performance in children after traumatic brain injury. Archives of Physical Medicine and Rehabilitation 1993; 74: 161-4.

11. Greenwald BD, Cifu DX, Marwitz JH, Enders LJ, Brown AW, Englander JS, et al. Factors associated with balance deficits on admission to rehabilitation after traumatic brain injury: a multicenter analysis. Journal of Head Trauma Rehabilitation 2001; 16: 238-52.

12. Shumway-Cook A, Olmscheid R. A systems analysis of postural dyscontrol in traumatically brain injured patients. Journal of Head Trauma Rehabilitation 1990; 5: 51-62.

13. Ingersoll CD, Armstrong CW. The effects of closed head injury on postural sway. Med Sci Sports Exerc 1992; 24: 739-743.

14. Wober C, Oder W, Kollegger H, Prayer L, Baumgartner C, Wober-Bingol C, et al. Posturographic measurements of body sway in survivors of severe closed head injury. Arch Phys Med Rehabil 1993; 74: 1151-6.

15. Graham DI. Neuropathology of head injury. In: Narayan RK, Wilberger JE, Povlishock JT, editors. Neurotrauma. McGraw Hill Cies inc, 1996.

16. Levin HS, Eisenberg HM, Benton AL, editors. Mild head injury. New-York: Oxford University Press; 1989.

17. Parasuraman R, Mutter SA, Molloy R. Sustained attention following mild closed head injury. Journal of clinical and experimental neuropsychology 1991; 13: 789-811.

18. Satz P, Zaucha K, McCleary C, Light R, Asarnow R, Becker D. Mild head injury in children and adolescents: a review of studies (1970-1995). Psychological Bulletin 1997; 122: 107-131.

19. Guskiewicz KM, Riemann BL, Perrin DH, Nashner LM. Alternative approaches to the assessment of mild head injury in athletes. Medicine and Science in Sports and Exercise 1997; 29 suppl: 213-221.

20. Guskiewicz KM. Postural stability assessment following concussion: one piece of the puzzle. Clinical Journal of Sport Medicine 2001; 11: 182-9.

21. Geurts ACH, Ribbers GM, Knoop JA, von Limbeek J. Identification of static and dynamic postural instability following traumatic brain injury. Archives of Physical Medicine and Rehabilitation 1996; 77: 639-44.

22. Geurts ACH, Knoop JA, van Limbeek J. Is postural control associated with mental functioning in the persistent postconcussion syndrome? Archives of Physical Medicine and Rehabilitation 1999; 80: 144-9.

23. Fay GC, Jaffe KM, Polissar NL, Liao S, Martin KM, Shurtleff HA. et al. Mild pediatric brain injury: a cohort study. Archives of Physical Medicine and Rehabilitation 1993; 74: 895-901.

24. Mild Traumatic Brain Injury committee (American Congress of Rehabilitation Medecine, Head Injury Interdisciplinary Special Interest Group): Journal of Head Trauma Rehabilitation 1993; 8: 86-87.

25. Sallis JF, Patterson TL, Buono MJ, Nader PR. Relation of cardiovascular fitness and physical activity to cardiovascular disease risk factors in children and adults. American Journal of Epidemiology 1988; 127: 933-941.

26. American Academy of Neurology. Report from the Quality Standards Subcommittee. Practice parameter: The management of concussion in sports (summary statement). Neurology 1997; 48: 581-585.

27. Bruininks RH. The Bruininks-Oseretsky Test of Motor Performance, Circle Pines, MN: American guidance service; 1978.

28. Crowe TK, Deitz JC, Richardson PK, Atwater SW. Interrater reliability of the Pediatric clinical test of Sensory Interaction for Balance. Physical and Occupational Therapy in Pediatrics 1990; 10: 1-27.

29. Westcott SL, Crowe TK, Deitz JC, Richardson P. Test-retest reliability of the pediatric clinical test of sensory interaction for balance. Physical and Occupational Therapy in Pediatrics 1994; 14: 1-22.

30. Wolfson LI, Whipple R, Amerman P. Stressing the postural response: a quantitative method for testing balance. Journal of the American geriatric Society 1986; 34: 845-850.

31. Shumway-Cook A, Horak FB: Assessing the influence of sensory Interaction on balance. Physical Therapy 1986; 66: 1548-1550.

32. Moss NE, Crawford S, Wade DT. Post-concussion symptoms: is stress a mediating factor? Clinical Rehabilitation 1994; 8: 149-56.

33. King NS, Crawford S, Wenden FJ, Moss NE, Wade DT. The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. Journal of Neurology 1995; 242: 587-92.

34. Swaine BR, Friedman DS. Activity restrictions as part of the discharge management for children with a traumatic brain injury. Journal of Head Trauma Rehabilitation 2001; 16: 292-301.

35. Levin HS, Outcome from mild head injury. In: Narayan RK, Wilberger JE, Povlishock JT, editors. Neurotrauma. McGraw Hill Cies inc, 1996.

36. Supplier of SPSS: SPSS® Base 10.0. SPSS Inc., 233 South Wacker Drive, 11th Floor, Chicago, IL, 60606-6307.

37. Haas G, Diener HC, Rapp H, Dichgans J. Development of feedback and feedforward control of upright stance. Developmental Medicine and Child Neurology 1989; 31: 481-8.

38. Forget R, Lamarre Y. Anticipatory postural adjustment in the absence of mormal peripheral feedback. Brain Research 1990; 508: 176-9.

39. Hirschfeld H, Forssberg H. Development of anticipatory postural adjustments during locomotion in children. Journal of Neurophysiology 1991; 66: 12-19.

40. Hatzitaki V, Zisi V, Kollias I, Kioumourtzoglou E. Perceptual-motor contributions to static and dynamic balance control in children. Journal of Motor Behavior 2002; 34: 161.

41. Forget R, Lamarre Y. Postural adjustments associated with different unloadings of the forearm: effects of proprioceptive and cutaneous afferent deprivation. Can J Physiol Pharmacol 1995; 73: 285-94

42. Chandler JM, Duncan PW, Studenski SA. Balance performance on the postural stress test: comparison of young adults, healthy elderly and fallers. Physical Therapy 1990; 70: 410-5.

43. Harburn KL, Hill KM, Kramer JF, Noh S, Vandervoort AA, Teasell R. Clinical applicability and test-retest reliability of an external perturbation test of balance in stroke subjects. Archives of Physical Medicine and Rehabilitation 1995; 76: 317-23.

44. Nolin P, Mathieu F. Déficits de l'attention et de la vitesse du traitement de l'information chez des enfants ayant subi un traumatisme crâniocérébral léger. Annales de Réadaptation et Médecine Physique 2000; 43: 236-45.

45. Keller M, Hiltbrunner B, Dill C, Kesselring J. Reversible neuropsychological deficits after mild traumatic brain injury. Journal of Neurology, Neurosurgery and Psychiatry 2000; 68: 761-4.

46. Echemendia RJ, Putukian M, Mackin S. Julian L, Shoss N. Neuropsychological test performance prior to and following sports-related mild traumatic brain injury. Clinical Journal of Sports Medicine 2001; 11: 23-31.

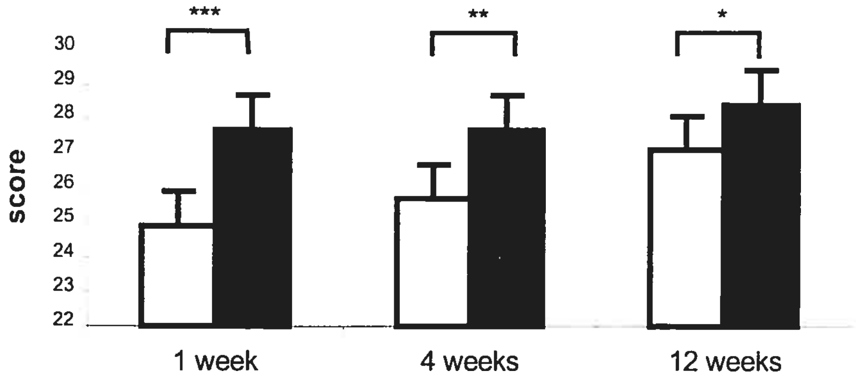


Figure 1: BOTMP Balance Subtest raw scores.
Raw score mean and standard error of the mean at one, four and twelve weeks for both groups on the Bruininks-Oseretsky Test of Motor Proficiency Balance Subtest. □:children with mTBI, ■:control children, ***: $p \leq 0.001$; **: $p \leq 0.01$; *: $p \leq 0.05$.

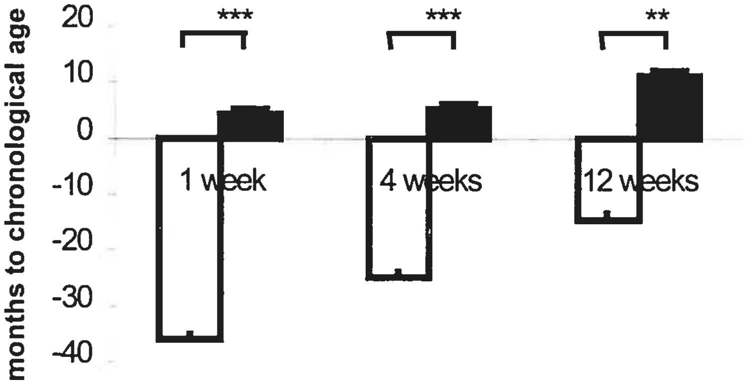


Figure 2: BOTMP Balance Subtest age equivalent scores.
Age equivalent scores (expressed in months to chronological age) mean and standard error of the mean at one, four and twelve weeks for both groups on the Bruininks-Oseretsky Test of Motor Proficiency Balance Subtest. □:children with mTBI, ■:control children, ***: $p \leq 0.001$; **: $p \leq 0.01$; *: $p \leq 0.05$.

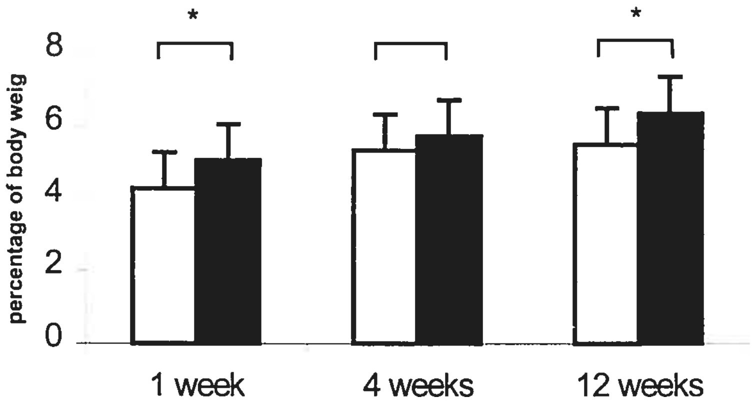


Figure 3: Postural Stress Test scores.
Percentage of the body weight required to induce a stepping postural reaction. Mean and standard error of the mean at one, four and twelve weeks for both groups. □:children with mTBI, ■:control children, ***: $p \leq 0.001$; **: $p < 0.01$; *: $p \leq 0.05$.

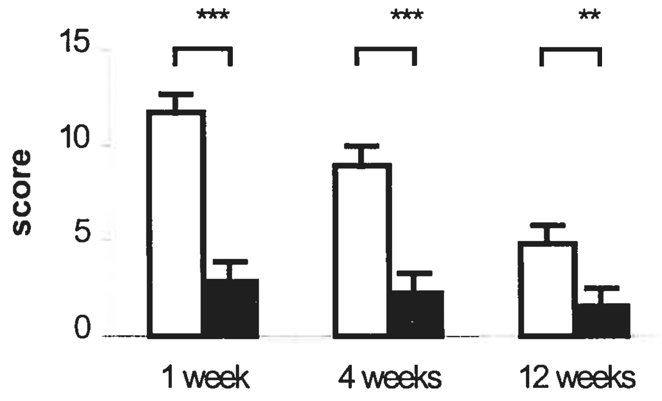


Figure 4: Rivermead Post-Concussion Symptoms Questionnaire scores.
Mean and standard error of the mean at one, four and twelve weeks for both groups on the Rivermead Post-Concussion Symptoms Questionnaire. □:children with mTBI, ■:control children, ***: $p \leq 0.001$; **: $p < 0.01$; *: $p \leq 0.05$.

Table 1: Characteristics of the mTBI children

Characteristics		**Frequency**	**Percentage**
Gender	Male	26	68
	Female	12	32
Cause of injury	Falls	16	42
	Bicycle falls	8	21
	Mva-bicycle	2	5
	MVA-ped	1	3
	MVA	1	3.
	Other (hits,etc…)	7	18
	missing	3	8
Site of impact	Posterior	16	42
	Left	9	24
	Anterior	8	21
	Right	4	10
	Missing	1	3
Admission GCS	13	1	3
	14	6	16
	15	31	81
Duration of LOC	No LOC	25	66
	0-10 minutes	11	29
	>10 minutes	2	5
Duration PTA	0-60 minutes	37	97
	>60 minutes	1	3
Concussion grade	1	0	0
	2	25	65
	3	13	35
Initial symptoms	Headache	32	84
	Nausea-vomitting	23	61
	Dizziness	16	42
	Visual problems	8	21
	Drowsiness	12	32
	Auditory problems	1	3

MVA: motor vehicle accident; GCS: Glasgow Coma Scale; LOC: loss of consciousness; PTA: post-traumatic amnesia

Table 2: Summary of the balance assessments

Domain/ name	Population tested (yrs)	Characteristics	Format	Psychometric properties			
				Reliability	Validity		
				Test-retest	Internal. Consistency	Construct	Concurrent
Balance							
Bruininks-Oseretsky Test of Motor Proficiency-Balance Subtest	4.5-14.5	Assessment of static and dynamic balance without external perturbations	-8 items -scored in time maintained in one position and pass/fail criteria	r=0.56	r=0.67	r = 0.57 whole test differences according to age, mental retardation and learning disabilities	r = 0.52-0.69 whole test with sensory interaction test
Pediatric-Clinical Test of Sensory Integration for Balance	4-9 (similar test exists with adults)	Measures amount of time subject can maintain a particular sensory condition	-12 sensory conditions -measured in time maintained and amount of sway recorded	r= 0.45-0.78 ICC= 0.79-0.82	--	r= .63-.68 differences between learning disability and cerebral palsy	--
Postural Stress Test	Adults	Measure of response to standardized external perturbations	-submit subject to perturbations and measured as % body weight required to elicit a stepping response	ICC=0.71-0.93 for hemiplegic patients	--	--	--

Table 3: Mean performances for the mTBI and control groups on the three balance tests and the Rivermead Post-Concussion Symptoms Questionnaire

			1 week	4 weeks	12 weeks
			Mean ± SD	Mean ± SD	Mean ± SD
BOTMP balance	Raw score	mTBI	24.9 ± 2.9	25.7 ± 3.1	27.1 ± 2.8
		Control	27.7 ± 2.4	27.7 ± 2.1	28.4 ± 2.3
	Age equivalent score	mTBI	-35.9 ± 39.6	-24.9 ± 43.4	-14.5 ± 42.9
		control	4.2 ± 36.4	5.1 ± 33.4	11.1 ± 35.3
PCTSIB (duration of stance in seconds)					
Tandem					
Floor	Eyes open	mTBI	29.8 ± 0.8	29.1 ± 3.2	29.3 ± 2.7
		control	29.4 ± 2.1	30.0 ± 0	30.0 ± 0
	Eyes closed	mTBI	22.1 ± 10.8	19.6 ± 10.8	22.0 ± 10.3
		control	23.5 ± 10.2	24.6 ± 9.5	25.6 ± 8.0
	Dome	mTBI	22.9 ± 10.1	22.1 ± 10.1	22.4 ± 10.2
		control	23.6 ± 10.5	23.3 ± 10.2	22.4 ± 9.1
Foam	Eyes open	mTBI	28.8 ± 5.1	27.8 ± 6.5	29.4 ± 3.7
		control	28.4 ± 5.1	29.3 ± 4.3	29.5 ± 1.7
	Eyes closed	mTBI	13.1 ± 10.2	15.4 ± 11.1	15.5 ± 12.1
		control	18.2 ± 10.2	18.4 ± 11.4	18.3 ± 11.1
	Dome	mTBI	13.5 ± 10.8	17.0 ± 11.2	18.3 ± 11.5
		control	15.6 ± 11.5	19.7 ± 11.3	19.6 ± 11.6
PCTSIB					
Single leg stance					
Floor	Eyes open	mTBI	27.7 ± 5.6	26.7 ± 6.7	27.8 ± 5.3
		control	28.1 ± 4.7	28.4 ± 4.9	27.6 ± 5.3
	Eyes closed	mTBI	13.2 ± 9.7	13.8 ± 10.5	14.3 ± 9.4
		control	13.0 ± 10.2	14.9 ± 9.6	16.7 ± 10.4
	Dome	mTBI	9.3 ± 9.5	22.1 ± 10.1	14.5 ± 10.0
		control	13.0 ± 10.5	23.3 ± 10.2	13.2 ± 10.7
Foam	Eyes open	mTBI	25.6 ± 8.2	25.0 ± 7.9	25.4 ± 7.9
		control	23.6 ± 9.5	26.8 ± 6.2	28.7 ± 5.2
	Eyes closed	mTBI	8.6 ± 7.8	6.7 ± 6.6	9.3 ± 8.1
		control	7.7 ± 7.1	10.4 ± 8.4	11.6 ± 10.3
	Dome	mTBI	4.3 ± 3.8	5.9 ± 5.8	7.8 ± 7.6
		control	5.8 ± 6.1	9.0 ± 9.7	8.3 ± 7.9
Postural stress test (percentage of body weight)		mTBI	4.3 ± 1.2	5.3 ± 1.5	5.5 ± 1.7
		control	5.0 ± 1.7	5.7 ± 1.6	6.3 ± 1.4
Rivermead questionnaire		mTBI	11.7 ± 10.2	8.9 ± 9.6	4.8 ± 5.7
		control	2.9 ± 3.4	2.3 ± 3.1	1.5 ± 2.1

BOTMP: Bruininks-Oseretsky Test of Motor Proficiency; PCTSIB: Pediatric Clinical Test of Sensory Interaction for Balance; mTBI: mild traumatic brain injury

4.2 Résultats concernant les capacités de temps de réponse suite au TCL

4.2.1 Article 3: Transient increase in response time after a mild head injury in children

Gagnon I, Swaine B, Friedman D, Forget R.. *Archives of Physical Medicine and Rehabilitation* Soumis

This research was supported in the form of grants by:
Fondation Marie Robert pour la recherche sur les traumatisés crâniens, Réseau provincial de recherche en adaptation-réadaptation (REPAR), Ordre professionnel des physiothérapeutes du Québec and the Physiotherapy Foundation of Canada. Gagnon I, Swaine B and Forget R receive bursaries and fellowships from the Fonds de la recherche en santé du Québec.

Part of this manuscript was at the American Congress of Rehabilitation Medicine, 79th Annual Meeting, Philadelphia, October 2-6, 2002; and was the abstract was published in Archives of Physical Medicine sand Rehabilitation 2002; 83: 1481

ABSTRACT

OBJECTIVE: Compare the visuo-motor response times of children after a mild head injury (mHI) with that of non-injured children matched for age, sex and pre-morbid level of physical activity. **DESIGN:** Prospective cohort study. **SETTING:** Pediatric trauma center. **PARTICIPANTS:** 38 children aged 7 to 16 years were assessed in each group. Children with mHI had a mean GCS of 14.8, and were considered normal on a neurological assessment at hospital discharge. Non-injured children were friends of those with mHI. **INTERVENTIONS:** Assessments of response time were conducted at 1, 4, and 12 weeks post-mHI and at corresponding time intervals for the control children. **MAIN OUTCOME MEASURES:** The response speed subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) and, reaction and movement time for upper and lower extremity, for simple, choice, and reversed choice response time paradigms. **RESULTS:** Over the assessment period, children with mHI performed worse than the control group only on the response speed subtest of the BOTMP ($p<0.05$). The mHI children however tended to have slower movement times 1 week post-injury ($p=0.026$) for the reversed choice response time paradigm for the lower extremities. **CONCLUSIONS:** Our results suggest that some children with mHI may have some problems in response time persisting until 12 weeks post-injury. Further research is required to better identify and understand the severity of these problems and determine their impact, if any, on participation in physical activities.

Keywords: Head injuries, pediatrics, response time

INTRODUCTION

The measurement of response time to various stimuli has been used to study concepts such as information processing following head injury (HI). Response times are non-specific markers of cognitive processes, as well as of the selection and execution of appropriate motor responses. According to an information processing framework based on the additive factor model[1-3], a response time can be divided into a reaction time and a movement time. A reaction time includes four stages, namely 1) feature extraction, 2) stimulus identification, 3) response selection, and 4) motor adjustment. Reaction time can be reduced if the individual is forewarned about stimulus presentation, and increased by interfering stimuli, other distractions, fatigue or cerebral damage following an injury[4]. Different paradigms exist to study reaction time. When the motor response is pre-determined and the response selection stage is omitted, the reaction time is designated as simple. When a choice of motor responses exists depending on the stimulus presented, it is designated as choice reaction time. In this model, the fifth stage consists of a movement time, referred to as response execution. It is usually unaffected by the manipulation of the stimulus and determined by the individual's ability to accelerate the body segments involved in the response and can be improved by practice.

A general slowing of reaction times with a relative preservation of movement times in different paradigms has been a consistent finding following severe HI among children and adults. Controversy remains however, concerning the stages of information processing that could be specifically affected after severe HI[4-6]. A deficit in information processing of non specific origin is in accordance with the diffuse nature of severe HI[7-8]. In the case of mild head injury (mHI), or cerebral concussion, where individuals usually perform within the normal limits on standard neuropsychological testing, the existence of a global slowing of cognitive processes is not consistently reported. Montgomery[9] identified an increase in mean reaction time of 300ms (using a visual four-choice paradigm) in a group of 26 adults with a mHI 24 hours post-injury when compared to a group of non-injured controls. The mHI subjects improved over the following weeks, but maintained significantly prolonged mean reaction times (100ms) when compared to the control group 6 weeks post-injury. Shum et al[4], on the other hand, compared a group of 7 adults with mHI and non-injured controls approximately 1 month post-injury, using various reaction time paradigms (visual four-choice reaction time task), and did not to find significantly increased reaction times following the injury despite the slightly increased reaction times found in the mHI group. Even fewer studies have investigated response time in children following mHI. Murray[5] extended Shum's work[4] and, using the same tasks as Shum, found that a group of 10 children with a mHI presented increased reaction time when compared to controls, but the difference did not reach statistical significance. It is however interesting to note that in Murray's study, reaction time was assessed at least 1 year post-injury as opposed to during the acute stage after mHI when difficulties may be more likely to be detected. More recent work[10] revealed, that children 2 weeks after a mHI, presented with a slowing of response time when compared to published norms for the Bruininks-Oseretsky Test of Motor Proficiency[11]. In the previously cited studies, children, like adults, are generally tested in a well stabilized sitting position and are asked to respond to visual or auditory stimuli by performing low amplitude movement of the upper extremities only requiring few body segments. These testing situations, although appropriate to investigate cognitive processes, are far from simulating the "real life" conditions children face when they are required to respond rapidly with appropriate postural and movement responses to environmental demands such as those included in physical activities.

Johnson[12] however, measured the ability of college athletes who had sustained a mHI to perform dynamic movements typically required in athletics. Here, individuals had to respond appropriately to visual stimuli by jumping (whole body displacement) on a mat consisting of 14 target sensors and the mean time required to complete 25 consecutive moves around the targets was recorded. The athletes performed this agility task pre-season and after a mHI, if they sustained one during the sports season. No significant differences were however found between the injured athletes' scores and those of the controls selected from the uninjured group. No reports on response time using whole body displacements could be found with children after a mHI despite the fact that school aged children represent the most active segment of the population[13]. Recent reports suggest the presence of balance deficits following a mHI in children[14-15] and this could have an impact on their ability to respond quickly when whole body displacements movements are involved. In fact, children with HI have been reported to be more at risk of subsequent HI than children with an orthopedic injury up to 12 months post-injury[16]. Balance difficulties combined with a slowing of response times could perhaps put children who have sustained even a mHI at risk for a subsequent injury. In this context, the investigation of response time in children is warranted.

The purposes of the present study were to 1) determine if children who sustained a mHI demonstrate visuo-motor response time deficits when compared to a group of non-injured children (matched for age, sex and premorbid level of physical activity); and 2) to describe the evolution of visuo-motor response time in the first three months following the injury. Both low amplitude upper extremity and whole body displacement motor responses were assessed using simple, choice and reverse choice paradigms. We hypothesized that children in the mHI group would present with increased response times compared to the control group, particularly for those activities demanding whole body displacements (involving balance) and in more complex situations involving more information processing (choice or reversed choice paradigms).

MATERIALS AND METHODS

Subjects

Forty children aged 7 to 16 years having sustained a mHI agreed to participate in this study. A mHI is defined by the American Congress of Rehabilitation Medicine[17] as including at least one of the following criteria; any period of loss of consciousness of 30 minutes or less, any loss of memory for events immediately before or after the accident lasting less than 24 hours, or a Glasgow Coma Score of 13-15 within 30 minutes of the injury. The children were recruited from consecutive hospital admissions to the Pediatric and Adolescent Trauma Program of the Montreal Children's Hospital, McGill University Health Center in Montreal, Canada. Criteria for such admissions include nausea, vomiting, headaches or any loss of consciousness. All children were considered normal on a standard neurological examination done prior to discharge from the hospital (usual stay of a few hours to overnight). Children were excluded if they presented with a documented medical diagnosis of learning or attention deficit disorder as well as regular use of Ritalin, attended a special school for learning or behavioral problems and, presented pre or post-injury co-morbidities limiting the assessment of upper extremity (UE) and lower extremity (LE) response time. As pre-morbid visuo-motor response times could not be obtained, the use of a control group of comparable non-injured children (friends) was essential to control for potential unidentifiable confounders. Similar exclusion criteria were used for a sample of 40 control children recruited among the friends of the mHI children and matched for age, sex, and pre-morbid level of physical activity. Pre-morbid level of physical activity was established using the Activity Rating Scale, a single 5-level question designed to assess the level of participation in physical activities in large epidemiological surveys[18]. Two children in the mHI group withdrew from the study after the initial evaluation for the following reasons: one moved out of the region and the other child's family decided not to continue to participate for personal reasons. Their matched control child was therefore removed from the data analysis to ensure similarity between the groups.

Measures

Response times were assessed among mHI and non-injured children using the response speed subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), and an apparatus developed specifically for this study to measure reaction time and movement time, for simple, choice and reversed choice paradigms for both upper and lower extremities (see below).

The response speed subtest of the BOTMP is part of a norm referenced test of global motor proficiency designed to discriminate between typically and atypically developing children. It assesses in the sitting position simple response time by having the child stop, as quickly as possible, a ruler from falling along a wall (moving visual stimulus). Before letting go of the ruler, the examiner offers an auditory warning ("ready") signaling the beginning of a preparatory interval (1 to 3s). As per the standardized test protocol, a score is recorded based on the displacement of the graduated ruler before the child can stop it with his thumb. Scores can range from 0 (ruler has fallen to the floor) to 17 (minimal displacement of the ruler).The median score of 7 consecutive trials at stopping the falling ruler is recorded as the subtest score. This BOTMP subtest has been used previously with this population in an exploratory study and was found to be able to identify problems in response speed among mHI children when compared to published test norms[10]. The BOTMP test battery has demonstrated good test-retest reliability (ICC varied between 0.56 and 0.86 for different subtests, 0.60 for response speed subtest) with two samples of typically developing children of different ages, and good internal consistency (alpha coefficient of 0.81).

Content and construct validity were also established for children of different age groups, and for children with varying levels of disability[11].

The apparatus developed for this study was adapted from a response time setup developed by Harbin[19] which was shown to discriminate between amateur and professional athletes. Our setup is described in figure 1. It consists of a mat (1.5m x1.5m) with an arrangement of 5 on/off pressure activated switches (30cm x 30cm) linked to a personal computer monitor that displays the same target arrangement as the switch plates. While the child stands on the center switch plate, the targets on the computer monitor light up in a random sequence and the child must respond by first jumping feet together to the plate corresponding to the lit up target, then, jumping back to the center plate as quickly as possible. This completes the sequence and initiates the delay for the presentation of the next "go" stimulus. This sequence is repeated for 16 trials and includes 4 random target directions and 4 different delays to the stimulus presentation (1 to 4 s.). The computer is programmed to record reaction and movement times in milliseconds. A similar mat was built on a smaller scale (mat size: 30cm x30cm; target size: 3cm x 3cm) to assess response times for the UE in the same manner. Here, in a stable sitting position, the child was required to use the index finger of his or her dominant hand to perform the motor response.

For both the UE and LE setups, three distinct response time paradigms were used: simple, choice and reversed choice response times. Simple response time was tested with a visual warning consisting of the target lighting up in a different color than that of the "go" stimulus, indicating the target to which the child had to respond. The visual warning was thought to help the children better direct their attention to the target and to control for possible vigilance problems. In the choice response time paradigm, any one of the 4 targets could light up without prior warning, thus testing the stimulus identification, the response selection and the motor adjustment stages of the information processing model. The reversed choice paradigm, where the child had to jump to or touch the plate opposite to that of the stimulus, was added to increase the complexity of the response selection stage. Specifically, the addition of stimulus-response direction incompatibility forced the child to move in the direction opposite to that of the stimulus. For all the tasks, the reaction time was defined as the time between the "go" stimulus and the time when the child left the center plate. Movement time was subdivided into two parts: 1) the "initial movement time" of jumping to the target plate and 2) the time it took to initiate the return to the middle plate (i.e. leaving the target plate), referred to as "change of direction time" (see figure 1).

In addition to the response time measures, information regarding the injury (Glasgow Come Scale score, concussion grade, duration of post-traumatic amnesia, duration of loss of consciousness, cause of injury, site of impact, initial symptoms) was obtained from the child's medical file. The Rivermead Post-Concussion Symptoms Questionnaire[20-21] was also administered at every assessment in order to document the presence and severity of 16 commonly experienced symptoms following mHI such as nausea and dizziness.

Procedure

Children meeting the study criteria and their parents were told about the research on the day of the admission to the trauma program. Those interested in participating were met on the same day by the study coordinator. Initial questionnaires, concerning the pre-morbid physical activity and sociodemographic information were then completed. Children were assessed at three different times: during the first week, and at four and twelve weeks post-injury. Children in the control group were assessed at corresponding time intervals. The assessment times were chosen because of their importance in the child's recovery. For example, the fourth week marks the end of an activity restriction period imposed on the child[22] and 12 weeks is the time when most post-concussion symptoms are generally reported as resolved[23]. All evaluations took place in the children's homes to minimize travelling inconvenience and school absenteeism. The evaluations, lasting approximately 1 hour, were performed by an experienced pediatric physical therapist who, to the best of our ability and for most of the children, was blind to group status. Tests were first explained to the child and a practice trial was permitted to allow familiarization with the procedure. The study received scientific and ethical approval from the Institutional Review Board of the Montreal Children's Hospital, McGill University Health Center. All children and their parents signed informed consent forms prior to data collection.

Data analysis

To verify the stability of all described outcome measures over time, intra-class correlation coefficients (ICC) were obtained for the control group between the first and second testing times (3-week interval) for all variables. The ICCs ranged between 0.39-0.84 with a mean of 0.69 showing that overall, the tests have adequate test-retest reliability.

For the BOTMP-response speed subtest, the raw score (computed from the median of the 7 trials), and age equivalent scores (derived from sub-test raw scores and expressed as the number of months above or below chronological age of published test norms) were computed for each child. For the response time apparatus, the reaction, initial movement and change of direction times were calculated for the simple, choice and reversed choice paradigms for both the UE and LE. These data are expressed in milliseconds and represent the mean of 16 trials (4 targets x 4 delays) since performances did not differ according to target direction nor to length of delay to stimulus presentation.

To address the study objectives, the test performances of the mHI children were compared to those of the children in the control group using two-way ANOVAs (group and time) with repeated measures on the time factor. Greenhouse Geiser corrections were used for all ANOVA results when the distribution of the variables departed from normality. Differences between groups at each assessment time were determined using independent t-tests with Bonferroni correction. The specific time effect for each group was determined using one-way ANOVA for repeated measures using Bonferroni correction for contrasts. In an attempt to identify subgroups of children presenting with the most significant deficits, relations between the injury variables and the injured children's performances on the each of the response speed tests were examined using chi-square analysis or Spearman rank order correlations when appropriate. As well, at each assessment time, the relation between the number of post-concussion symptoms and the children's performances on the response speed tests was explored using Spearman rank order correlations. The SPSS statistical package, version 10.0, was used for all analyses[24].

RESULTS

The characteristics of the mHI children, presented in table 1, are consistent with that found in the literature with boys representing 68% of the sample, falls being the most frequent etiology and headaches and nausea being the most frequent initial symptoms present. The average admission GCS was 14.8, illustrating the very mild nature of the HI sustained by the children. Sixty-six percent of children sustained a mHI that can be classified as a grade 2 concussion as per the American Academy of Neurology practice parameters[25] and 34 percent sustained a grade 3 concussion. The mHI children described themselves as slightly more active than children their own age and sex (Activity Rating Scale 3.5±0.9) and the control children were matched accordingly. The mHI children had a mean age of 12.2 ± years while the controls had a mean age of 12.0 ± years. The descriptive statistics for both groups and for all tests are presented in table 2. The results of the BOTMP response speed subtest raw score, and age equivalent score, are presented in figures 2a and 2b, respectively.

The ANOVA performed on the BOTMP raw score revealed that there were no statistically significant differences between the groups across all testing sessions although a strong tendency could be observed. (F=3.71; p=0.06). There was a main effect for the time factor (repeated measure) (F=3.41; p=0.04). A group x time interaction was found for the performances of the injured and non-injured children (F=4.51; p=0.013). The mHI children performed worse (t=-3.39; $p<0.001$) than those non-injured only at 1 week post-injury. When the groups were taken separately, the time effect was only present for the mHI group (F=5.69; p=0.005). The injured children presented with lower scores in the first week when compared to those of the fourth (p=0.03) and of the 12th (p=0.009) week.

For the BOTMP age equivalent scores, there was a strong between group effect (mHI vs controls) (F=19.60; $p<0.001$). There was no main effect for the time factor (repeated measure) (F=0.172; p=0.842), however there was a group x time interaction for the performances of the injured and non-injured children (F=6.02; p=0.003). Specifically, the mHI children performed worse than the control group at week 1 (t=-5.18; $p<0.001$) and week 12 (t=-3.99; $p<0.001$). The performances of the control group were found to change over time (F=3.34; p=0.04); the children had a slightly better performance at week one compared to week four (p=0.05).

The results obtained with the response time apparatus revealed that for the UE and LE, reaction times for the reversed choice paradigm were significantly greater (approximately 100 ms) than those found for the simple and choice paradigms (see table 2). Clearly this reflects that the reversed choice paradigm was the most complex task.

The ANOVAs performed on the response time apparatus results revealed that there was no between group effect (mHI vs control) for reaction, movement and change of direction times for all paradigms of the UE and LE. However, the children with mHI tended to perform worse than children in the control group for initial movement (F=3.46; p=0.06) and change of direction time (F=1.96; p=0.16) of the reversed choice paradigm, the most complex task for the lower extremities. This trend appeared to be primarily present at week one when the mHI children performed worse than the control subjects when moving (t=1.38; p=0.173) and changing direction (t=2.26; p=0.026) (figure 3a and b respectively).

For the UE test, there was a main effect for the time factor for 2 conditions namely: initial movement time (F=5.13; p=0.01) and change of direction time (F=7.53; p=0.003) of the simple response time paradigm. The time effect for both groups was found between the initial and the four week evaluations for initial movement time (F=11.19; p=0.001) and change of direction time (F=6.66; p=0.01) as there was a significant improvement in performances over that period.

For the LE testing there was a main effect for the time factor for 3 conditions namely: reaction time (F=4.11; p=0.03) and initial movement time (F=3.81; p=0.03) of the choice response time paradigm for the LE, and change of direction time (F=4.60; p=0.01) of the reversed choice response time paradigm. The time effect for both groups was found between the initial and the four week evaluations for the reaction time (F=12.52; p=0.001) of the choice response time paradigm where the children's performance deteriorated slightly. For the other conditions, initial movement time (F=5.93; p=0.02) of the choice response time paradigm for the LE, and change of direction time (F=4.03; p=0.05) of the reversed choice response time paradigm for the LE, the time effect was found between the fourth and twelfth week evaluations. For the former condition, children demonstrated a slight deterioration in their performances and for the latter, they improved over that period. There was no group x time interaction for any of the testing conditions for the upper or lower extremities.

As for post-concussion symptoms (figure 4), there was a strong between group effect across all testing sessions ($F=20.11$; $p<0.001$) with the mHI children reporting a significantly greater number of symptoms than the control group at all testing times. There was a main effect for the time factor ($F=23.41$; $p<0.001$) (repeated measure) and there was a group x time interaction ($F=10.79$; $p<0.001$) for the performances of both groups. Specifically, the time effect was strong for the mHI group ($F=20.59$; $p<0.001$) and children improved between weeks 1 and 4 ($p=0.002$) and weeks 4 and 12 ($p=0.002$). On the other hand, the time effect was weaker for the control group ($F=3.35$; $p=0.04$). There was no significant relation between the number of post-concussion symptoms and response speed scores. Subgroup analyses revealed that no injury related variable was able to differentiate among the performances of the injured children.

DISCUSSION

The findings of this study suggest that children with mHI demonstrate similar response times as compared to a control group of non-injured children on the majority of the tests used. Significant differences between the groups were noted only on the BOTMP response speed subtest, a seemingly simple test. It is important to note that it is the second time that this test was able to detect response time problems after a mHI[10]. Perhaps the multiple modalities (auditory warning, visual stimulus) involved in this simple task may be a factor explaining the increase in response time shown by the mHI group. In previous work with adults after severe HI, Zahn[26] reported that the presence of multiple modalities was related to an increase in reaction time. This was suggested to relate to difficulties in shifting attention from one modality to another or to an inability in preparing optimally to two modalities within the same task. In the present study, sensory modalities that were different for the warning signal and actual stimulus could have added a degree of difficulty to the task and thus been a greater strain on information processing.

Beyond the presence of the multiple sensory modalities, the nature of the visual stimulus may have played a role in the test's ability to detect differences between the two groups. The perception of visual stimuli is generally achieved through the attributes of the stimuli themselves. When objects are defined by attributes such as luminance and color, they are said to possess "first order" properties. On the other hand, when objects can only be perceived by their motion, texture, or depth they are said to have "second order" properties and additional information processing is required to perceive the image[27-28]. In the BOTMP response speed subtest, it is the movement of the ruler that is the stimulus for the task and the difficulties experienced by the mHI children could have been related to the visual detection of the movement itself. Motion detection difficulties following HI have not been examined specifically, however, processes such as aging and some brain injuries have been shown to affect the ability to detect complex stimuli such as motion and texture (second order) more than the ability to perceive less complex (first order) visual stimuli[29-31].

Surprisingly, the apparatus used to test the dynamic movements (e.g. whole body displacement) did not detect significant differences between the performances of the injured and non-injured children. Johnson[12] using a similar test, was not able to differentiate between the performances of injured and non-injured athletes. One might argue that the children with mHI may simply not have had problems with dynamic movements or that this type of apparatus or the chosen paradigms may not have been sensitive enough to detect differences between the groups if in fact they did exist.

The observed trend that the mHI children had prolonged movement and change of direction times in the reversed choice paradigm for the LE warrants some discussion. In the information processing model described earlier, movement time is a separate stage of information processing[1-3] and has been found by some to be unimpaired after mHI[4]. In the present study, movement times were also found to be unimpaired for all but one paradigm (reversed choice and only for the LE). The fact that the reversed choice paradigm was similar for both groups for the UE but tended to be different among the groups for the LE suggests that the problems may not simply be attributed to slowed information processing but could be related in some way to balance difficulties. In fact, we recently found that the same group of children presented with balance difficulties as measured with clinical tools including the Postural Stress Test[15]. On the other hand, balance difficulties may not be solely responsible for the trend in increased movement times since the other LE performances were not affected on the other paradigms. This trend is thus more likely to be due to the complexity arising from the combination of balance and information processing that could have stressed the child's functioning to the point of perturbing their responses.

Finally, children in the mHI group reported significantly more post-concussion symptoms at all testing times than did those in the control group. The persisting differences between the groups could possibly indicate the incomplete resolution of the functional disruption of the CNS following a mHI even three months post-injury. There is however, no proof that this disruption is associated with the observed information processing problems due to the lack of relationship between post-concussion symptoms and response speed scores. Although the Rivermead Post-Concussion Symptoms Questionnaire used in this study had previously been used only with adults after mHI, this scale may prove useful in standardizing the self-reporting of the subjective symptoms encountered in post-concussion syndrome among children.

Conclusion

Children with mHI do not present with response time deficits when assessed using classical response time paradigms. Only in particular situations, such as when assessed with simple tasks involving moving visual stimuli or with tasks involving balance and more complex information processing, can deficits be found initially and, in some cases, up to the twelfth week post-injury. Further research is required to better identify and understand the severity of these problems and determine their impact, if any, on participation in physical activities and perhaps on the risk for subsequent injury. Our results suggest that some children with mHI may still have problems in response time persisting beyond the period of restricted activities, that could affect their performance in physical activities. Given that some of these children may have problems in response time and balance, the guidelines should perhaps be used with caution when returning children to demanding physical activities.

AKNOWLEDGEMENTS

The authors wish to thank the children and their families for their generous participation in the research project as well as the neurotrauma program coordinator of the Montreal Children's Hospital, McGill University Health Center for his collaboration in the recruitment of the children.

REFERENCES

1. Sternberg S. On the discovery of the processing stage. Acta Psychol 1969; 30: 276-315.

2. Van Zomeren AH, Brouwer WH, Deelman BG. Attentional deficits: the riddles of selectivity, speed and alertness. In N. Brooks editors, Closed head injury: psychological, social and family consequences. Oxford: Oxford University Press 1984, 74-107.

3. Van Zomeren AH, Brouwer WH. Clinical neuropsychology of attention. New York: Oxford University Press, 1994.

4. Shum DHK, McFarland K, Bain JD, et al. Effects of closed-head injury on attentional processes: an information-processing stage analysis. J Clin Exp Neuropsychol 1990; 12: 247-64.

5. Murray R, Shum D, McFarland K. Attentional deficits in head-injured children: an information processing analysis. Brain Cognition 1992; 18: 99-115.

6. Stablum F, Leonardi G, Mazzoldi M, et al. Attention and control deficits following closed head injury. Cortex 1994; 30: 603-18.

7. Ponsford J, Kinsella G. Attentional deficits following closed-head injury. J Clin Exp Neuropsychol 1992; 14: 822-38.

8. Stokx LC, Gaillard WK. Task and driving performance of patients with a severe concussion of the brain. J Clin Exp Neuropsychol 1986; 8: 421-36.

9. Montgomery, E.A., Fenton, G.W., McLelland, R.J., et al.: The psychobioloby of minor head injury. Psychol Med, 21: 375-384, 1991.

10. Gagnon I, Forget R, Sullivan SJ, et al. Motor performance following a mild traumatic brain injury in children: an exploratory study. Brain Injury 1998; 12: 843-853.

11. Bruininks RH. The Bruininks-Oseretsky Test of Motor Performance, Circle Pines, MN: American guidance service; 1978.

12. Johnson PD, Hertal J, Olmsted LC, et al. Effects of mild brain injury on an instrumented agility task. Clin J Sport Med 2002; 12: 12-17.

13. Kino-Québec. L'activité physique, déterminant de la santé des jeunes, avis du comité scientifique de Kino-Québec, Secrétariat au loisir et au sport, ministère de la Santé et des Services sociaux, Gouvernement du Québec, 2000.

14. Gagnon I, Friedman D, Swaine B, et al. Balance findings in a child before and after a mild head injury. J Head Trauma Rehabil 2001; 16: 595-602.

15. Gagnon I, Forget R, Swaine B, et al. Balance findings after a mild head injury in children. 3rd World congress of Neurorehabilitation, Venise, Italie, 2-6 avril 2002, Neurorehabil Neural Repair. 2002; 16: 22-23.

16. Swaine B, Marosi E. Exploring the possible association between previous head injury and head injury among children. Acta Neurochir 2002; 144: A34-45.

17. Mild Traumatic Brain Injury committee (American Congress of Rehabilitation Medecine, Head Injury Interdisciplinary Special Interest Group): J Head Trauma Rehabil 1993; 8: 86-87.

18. Sallis JF, Patterson TL, Buono MJ, et al. Relation of cardiovascular fitness and physical activity to cardiovascular disease risk factors in children and adults. Am J Epidemiol 1988; 127: 933-941.

19. Harbin, G., Durst L., Harbin, D.: Evaluation of oculomotor response in relationship to sports performance. Med Sci Sport Exercise, 21: 258-262, 1989.

20. Moss NE, Crawford S, Wade DT. Post-concussion symptoms: is stress a mediating factor? Clin Rehabil 1994; 8: 149-56.

21. King NS, Crawford S, Wenden FJ, et al. The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. J Neurol 1995; 242: 587-92.

22. Swaine BR, Friedman DS. Activity restrictions as part of the discharge management for children with a traumatic brain injury. J Head Trauma Rehabil 2001; 16: 292-301.

23. Levin HS, Outcome from mild head injury. In: Narayan RK, Wilberger JE, Povlishock JT, editors. Neurotrauma. McGraw Hill Cies inc, 1996.

24. Supplier of SPSS: SPSS® Base 10.0. SPSS Inc., 233 South Wacker Drive, 11th Floor, Chicago, IL, 60606-6307.

25. American Academy of Neurology. Report from the Quality Standards Subcommittee. Practice parameter: The management of concussion in sports (summary statement). Neurology 1997; 48: 581-585.

26. Zahn TP, Mirsky AF. Reaction time indicators of attention deficits in closed head injury. J Clin Exp Neuropsychol 1999; 21: 353-67.

27. Cavanagh P, Mather G. Motion: the long and short of it. Spatial Vision 1989; 4: 103-129.

28. Faubert J. Visual perception and aging. Can J Exp Psychol 2002; 56: 164-176.

29. Schmidt RA. Motor control and learning: a behavioral emphasis. 2nd ed. Champaign, Ill: Human Kinetics Inc; 1988.

30. Schenk T, Zihl J. visual motion perception after brain damage: I. Deficits in global motion perception. Neuropsychologia 1997; 35: 1289-97.

31. Habak C, Faubert J. Larger effect of aging on the perception of higher order stimuli. Vision Research 2000; 40: 943-50.

Table 1: Characteristics of the children with mild head injury

Characteristics		Frequency	Percentage
Gender	Male	26	68
	Female	12	32
Cause of injury	Falls	16	42
	Bicycle falls	8	21
	MVA-bicycle	2	5
	MVA-pedestrian	1	3
	MVA	1	3.
	Other (hits,etc...)	7	18
	missing	3	8
Site of impact	posterior	16	42
	left	9	24
	anterior	8	21
	right	4	10
	missing	1	3
Admission GCS	13	1	3
	14	6	16
	15	31	81
Duration of LOC	No LOC	25	66
	0-10 minutes	11	29
	>10 minutes	2	5
Duration PTA	0-60 minutes	37	97
	>60 minutes	1	3
Concussion grade	1	0	0
	2	25	66
	3	13	34
Initial symptoms	Headache	32	84
	Nausea-vomitting	23	61
	Dizziness	16	42
	Visual problems	8	21
	Drowsiness	12	32
	Auditory problems	1	3

GCS: Glasgow Coma Scale; LOC: Loss of consciousness; PTA: Post-traumatic amnesia; MVA: Motor vehicle accident;

Table 2: Mean performances for the mild head injury and control groups on response time tests

			1 week	**4 weeks**	**12 weeks**
			Mean ± SD	Mean ± SD	Mean ± SD
BOTMP response speed	Raw score	MHI	9.1± 2.9	10.3 ± 23.0	10.3 ± 3.0
		control	11.1 ± 2.5	10.8 ± 2.9	11.2 ± 2.2
	Age equi	MHI	-18.8 ± 37.0	-5.3 ± 36.0	-10.8 ± 32.5
		control	20.5 ± 28.8	9.7 ± 28.5	16.4 ± 26.4
Response time apparatus (scores in milliseconds)					
Upper extremity					
Simple	Reaction time	MHI	962 ± 205	923 ± 175	920 ± 131
		Control	914 ± 280	887 ± 231	856 ± 197
	Initial movement time	MHI	476 ± 460	327 ± 213	362 ± 342
		Control	457 ± 320	356 ± 269	409 ± 249
	Change of direction time	MHI	150 ± 75	126 ± 56	121 ± 58
		Control	138 ± 73	118 ± 40	108 ± 37
Choice	Reaction time	MHI	892 ± 211	999 ± 595	907 ± 150
		Control	856 ± 232	853 ± 258	896 ± 228
	Initial movement time	MHI	371 ± 268	378 ± 239	364 ± 226
		Control	477 ± 405	422 ± 298	389 ± 308
	Change of direction time	MHI	124 ± 47	113 ± 41	122 ± 68
		Control	127 ± 79	126 ± 66	121 ± 79
Reversed choice	Reaction time	MHI	1079 ± 188	1063 ± 181	991 ± 191
		Control	1042 ± 262	1001 ± 250	1016 ± 224
	Initial movement time	MHI	421 ± 238	400 ± 280	475 ± 342
		Control	488 ± 342	439 ± 363	403 ± 276
	Change of direction time	MHI	131 ± 57	117 ± 52	117 ± 55
		Control	134 ± 49	125 ± 64	122 ± 78
Lower extremities					
Simple	Reaction time	MHI	1343 ± 182	1346 ± 193	1360 ± 202
		Control	1344 ± 180	1354 ± 151	1330 ± 174
	Initial movement time	MHI	185 ± 101	180 ± 83	212 ± 97
		Control	204 ± 167	193 ± 127	201 ± 77
	Change of direction time	MHI	337 ± 132	330 ± 127	305 ± 103
		Control	306 ± 120	297 ± 84	294 ± 77
Choice	Reaction time	MHI	1326 ± 176	1382 ± 160	1370 ± 196
		Control	1297 ± 146	1345 ± 143	1343 ± 258
	Initial movement time	MHI	189 ± 81	177 ± 71	208 ± 97
		Control	178 ± 55	179 ± 71	202 ± 73
	Change of direction time	MHI	320 ± 146	315 ± 139	278 ± 103
		Control	282 ± 96	289 ± 88	286 ± 67

			1 week	4 weeks	12 weeks
			Mean ± SD	Mean ± SD	Mean ± SD
Reversed choice	Reaction time	MHI	1509 ± 248	1521 ± 280	1472 ± 293
		Control	1482 ± 193	1493 ± 186	1461 ± 161
	Initial movement time	MHI	282 ± 302	292 ± 245	215 ± 103
		Control	206 ± 72	211 ± 11	219 ± 92
	Change of direction time	MHI	332 ± 145	308 ± 122	282 ± 110
		Control	279 ± 88	279 ± 83	271 ± 65

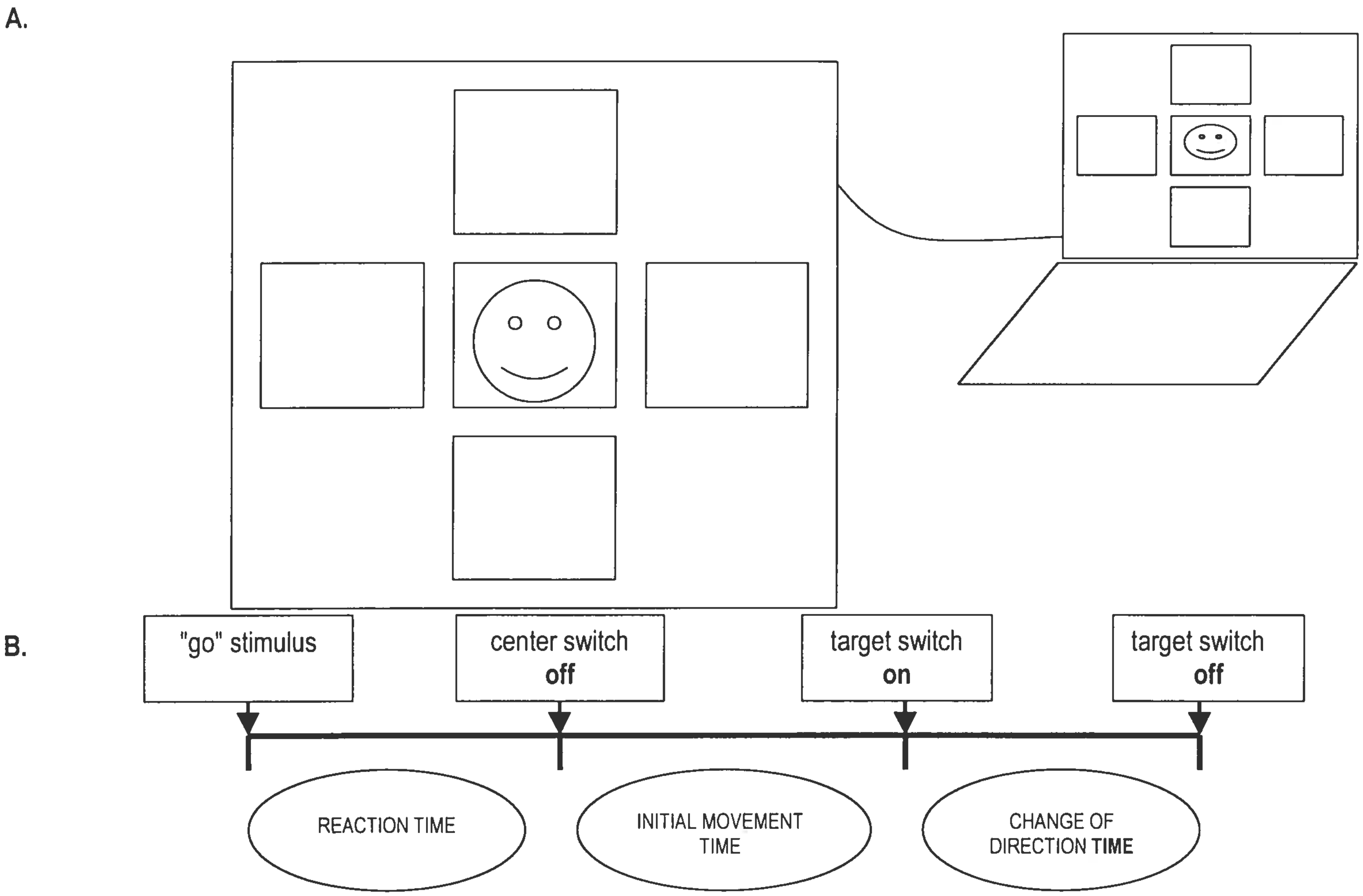


Figure 1: A. Response time apparatus designed for the study. B. Operational definitions of reaction and movement times measured with the response time apparatus.

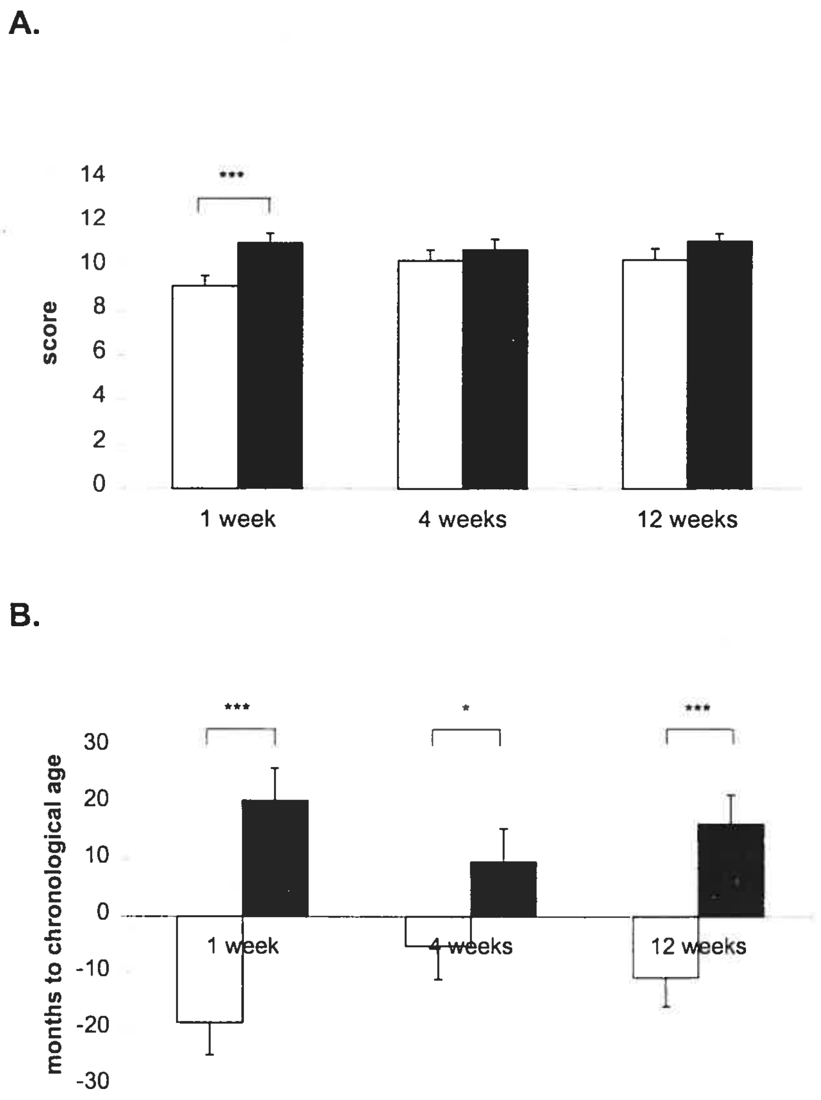
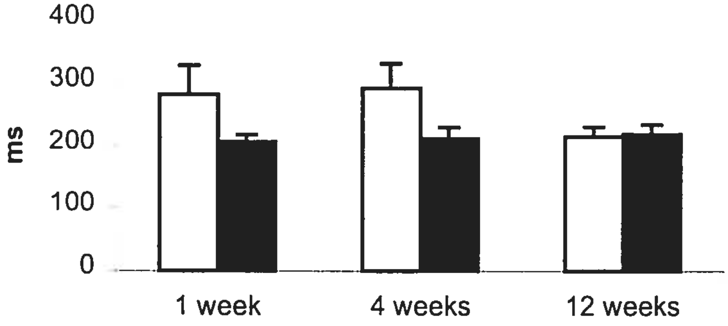


Figure 2: Bruininks-Oseretsky Test of Motor Proficiency-Response Speed Subtest. Mean raw scores (A) and age equivalent scores (B) for children with MHI (☐) and control children (■) at 1, 4 and 12 weeks. The maximal raw score is 17 and the age equivalent score is expressed in months deviating from the child's chronological age. Error bars are 1 standard error of the mean. ***: $p < 0.001$.

A.



B.

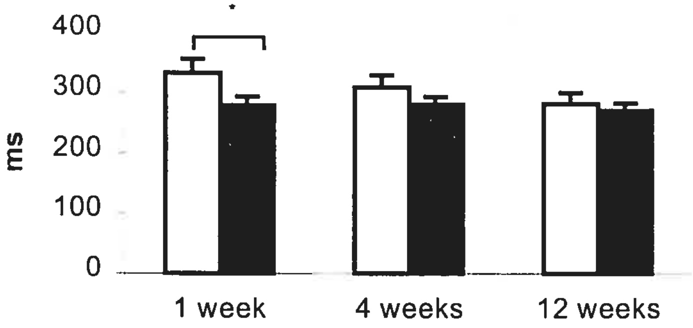


Figure 3: Response Time Apparatus. Mean performance of children with MHI (☐) and control children (■) at 1, 4 and 12 weeks for the lower extremity reversed choice paradigm. Initial movement time (A) and change of direction time (B) are expressed in milliseconds. Error bars are 1 standard error of the mean. *: $p < 0.05$.

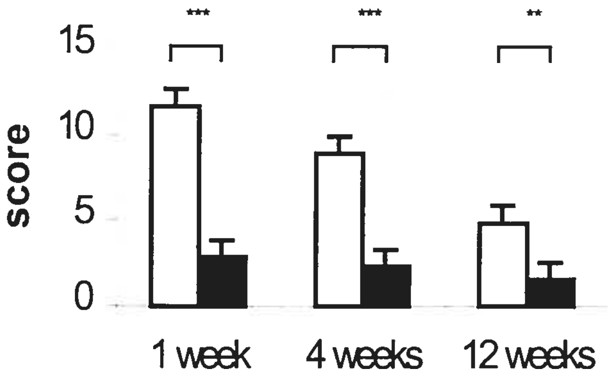


Figure 4: Rivermead Post-Concussion Symptoms Questionnaire scores. Mean scores of children with MHI (□) and control children (■) at 1, 4 and 12 weeks. ***: $p<0.001$; **: $p<0.01$.

4.3 Résultats concernant le retour aux activités physiques suite au TCL

4.3.1 Article 4: Mild traumatic brain injury affects children's self-efficacy related to their physical activity performance

Gagnon I, Swaine B, Friedman D, Forget R.. *Pediatrics*. Soumis

This research was supported in the form of grants by:
Fondation Marie Robert pour la recherche sur les traumatisés crâniens, Réseau provincial de recherche en adaptation-réadaptation (REPAR), Ordre professionnel des physiothérapeutes du Québec and the Physiotherapy Foundation of Canada. Gagnon I, Swaine B and Forget R receive bursaries and fellowships from the Fonds de la recherche en santé du Québec.

Part of this manuscript was presented at the 7th annual conference of the Euroacademia Multidisciplinaria Neurotrumatologica, Newcastle-upon-Tyne, UK, June 2002, and the abstract was published in Acta Neurochirurgica, 2002; 144(7): A35

.

ABSTRACT

OBJECTIVE: Little is known about how a mild traumatic brain injury (mTBI) might affect children's return to physical activities. The primary purpose of this study was to determine whether children who had sustained a mTBI practiced their physical activities 12 weeks after the injury with the same level of self-efficacy as prior to the injury, and to compare these levels of self-efficacy with that of a group of non-injured children matched for age, sex and premorbid level of physical activity. METHODS: 34 children (mean:12 ± 3yr.) were recruited in each group. Children with mTBI had been admitted to hospital for an observation period of several hours to an overnight stay, had a mean GCS of 14.8, were considered normal on a standard neurological assessment at hospital discharge, and were all allowed to resume physical activities 4 weeks after the injury. Children with mTBI were assessed 1 day post-injury, to document pre-injury status, and at 12 weeks post-mTBI using a self-efficacy questionnaire developed for this study, the Physical Activity Questionnaire (level of physical activity), the Athletic Competence subscale of the Self-Perception Profile for Children or Adolescents (athletic competence) and the Rivermead Post-Concussion Symptoms Questionnaire. Non injured children underwent the same assessments at a corresponding time interval. RESULTS: MTBI children scored significantly worse than those non-injured the self-efficacy questionnaire at 12 weeks post-injury, while they maintained similar levels of physical activity participation and athletic competence CONCLUSION: Although mTBI children had returned to their pre-injury level of physical activity and had maintained their athletic competence, they did not feel as confident in their ability to perform their physical activities at 12 weeks post-injury as compared to how they felt before the injury.

Introduction

A mild traumatic brain injury (mTBI) or cerebral concussion is an injury that is generally thought to have little consequences past the immediate resolution of initial symptoms. Consequently, most children are instructed to gradually resume their physical activities post-injury as suggested in current management protocols (1). Little is known, however, about how a mTBI might impact children's performance in physical activities. Anecdotal evidence from clinicians suggests that some children may have problems in performance when returning to both structured and unstructured physical activities. Children have reported, up to three and four months following the injury, that they do not feel "quite like before" or feel they are not able to perform as well as they did before the injury. In other words, they appear to lack confidence in their performance in physical activities following even a mTBI. These reported difficulties could be due to a number of factors because performance in physical activities is a multifactorial concept, related to both physical and non-physical factors. In terms of physical factors, recent reports have identified impairments in balance and visuo-motor response times following pediatric mTBI (2-5), although no empirical evidence exists to support that these are the cause of the performance difficulties. Non-physical factors, such as motivation or self-efficacy, if affected post-injury could also have an influence on children's performance.

Self-efficacy is defined as "people's beliefs in their capabilities to organize and execute courses of action required to perform a given behavior" (6). These beliefs are derived from four major sources of information; 1) previous performance of the behavior, 2) physical and emotional state when enacting the behavior, 3) observations of others and 4) encouragement from others. Previous performance is the most significant source of information that influences self-efficacy beliefs and failures encountered during previous attempts can alter the feelings of efficacy for future participation in physical activities (7-9). A strong association exists between self-efficacy and actual performance. Bandura (6) has postulated that, in the context of physical activities, significant injuries can negatively affect self-efficacy and subsequently negatively affect performance even after the resolution of the initial injury. This hypothesis has been supported in the case of severe injury with significant life-changing consequences but not in the case of more minor musculoskeletal injuries having limited long term physical repercussions (10). Specifically, Kilgore (10) found no decrease in self-efficacy among college women gymnasts after ligament sprains and muscle injuries when assessed prior to competitive meets throughout the season. Self-efficacy differs from perceived athletic competence that is a personality trait that is more related to participation in physical activities rather than to the performance itself (11-12). Perceived athletic competence is a determining factor when choosing whether or not to engage and persist in physical activities, while self-efficacy is a situation-specific form of self-confidence that can influence performance in the activities in which individuals choose to participate.

To our knowledge, self-efficacy related to physical activities has never been explored in children post-mTBI. This is important to examine since the goal of rehabilitation is to ensure optimal recovery after the injury, including participation in physical activities and satisfaction with performance. The examination of self-efficacy beliefs with respect to performance in physical activities is an important step towards a better understanding of the causes of reported feelings of decreased performance following a mTBI. If children do not feel as confident in their ability to perform their regular physical activities as before their injury, they might be at risk of re-injury. The purpose of this exploratory study was therefore to determine whether children who sustained a mTBI practiced their activities at 12 weeks after the injury with the same level of self-efficacy as prior to the injury, and to compare these levels of self-efficacy with that of a group of non-injured children matched for age, sex and premorbid level of physical activity. The secondary objective was to explore the relationships between the injured children's self-efficacy levels and their level of participation in physical activities, their level of perceived athletic competence and their post-concussion symptoms reported during the recovery period.

Methods

Sample

Thirty-four children aged 8 to 16 years (mean:12 ± 3yr.), having sustained a mTBI, as defined by the American Congress of Rehabilitation Medicine (13), agreed to participate in this study. The children were recruited from consecutive admissions to the Pediatric and Adolescent Trauma Program of the Montreal Children's Hospital, McGill University Health Center in Montreal. Criteria for such admission include nausea, vomiting, drowsiness, headaches or any loss of consciousness. All children were considered normal on a standard neurological exam done just prior to discharge from the hospital (usual stay of a few hours to overnight). Children were excluded if they presented a documented medical diagnosis of learning or attention deficit disorder as well as regular use of Ritalin, attended a special school for learning or behavioral problems and, presented pre or post-injury co-morbidities limiting the assessment of balance and response times. Similar exclusion criteria were used for a sample of 34 control children recruited, whenever possible, among the friends of the mTBI children and matched for age, sex, and pre-morbid level of physical activity. With this method of "friend sampling", we attempted to control for socioeconomic level and other potential confounders. For the eight children who could not provide the name of a friend interested in participating, control children were recruited among the authors' colleagues and friends using the same matching criteria. Pre-morbid level of physical activity was established using the Activity Rating Scale, a single 5-level question designed to assess the level of participation in physical activities in large epidemiological surveys (14-15).

Measures

Four measures were administered to all the children. To our knowledge, this is the first time they have been used with children after a mild TBI. The first one of these measures was a questionnaire developed to assess children's level of self-efficacy. In the context of this study, we used Bandura's conceptualization of self-efficacy (6) and defined self-efficacy in physical activities as an individual's belief and confidence in his ability to participate and succeed in a satisfactory manner in physical activities appropriate for this individual. Because self-efficacy is situation- or disease-specific, a new tool must be developed for its measurement every time it is investigated in a new context. For example, tools to measure self-efficacy have been developed to study the management of diseases such as arthritis, epilepsy or multiple sclerosis (8, 16-17). The self-administered questionnaire developed for this study was constructed using a standardized method (18). First, two dimensions of self-efficacy were identified as important to include in the tool. In order to address the specificity of mTBI as a condition, the first dimension was concerned with the child's confidence in overcoming potential problems after mTBI such as fatigue, pain, balance or slowness while practicing his or her physical activities. Because we also wanted to examine self-efficacy from a physical activity point of view without reference to the mTBI, the second dimension addressed the general athletic skills required to practice physical activities. The choice of items for these dimensions was based on an extensive review of the related literature and discussions with experienced clinicians working with this clientele. The literature was reviewed using the Sportsdiscus, Psychinfo, CINHAL and Medline databases between 1990 and 2000 and using textwords such as self-efficacy, physical activitiy performance, mild traumatic brain injury and concussion. Second, the questionnaire was submitted to an expert in the measurement of self-efficacy to verify the pertinence and clarity of each item and to ensure face and content validity. Changes were subsequently made to the content and wording of certain items and some items were removed. The final version of the questionnaire consisted of 18 items covering the two dimensions: eight items related to mTBI problems and ten items related to athletic skills (annex 1). When making confidence judgements about the items, children were asked to refer to the list of activities recalled in the Physical Activity Questionnaire (see below) to anchor the items to activities that the children had actually practiced during the testing period. The items were scored on a 10-point scale with confidence ratings ranging from 10% to 100% where higher scores represented higher self-efficacy. For example, a score of 80% on an item would mean that the child felt 80% confident with respect to that item. A total score for each dimension was obtained.

Three other assessment tools were used in order to address the secondary objective of the study. The Physical Activity Questionnaire (PAQ) (19-20) documented the level of participation in regular physical activities, the Athletic Competence (AC) subscale of the Self-Perception Profile for children or adolescents (21-22) addressed perceived competence in physical activities and the Rivermead Post-Concussion Symptoms Questionnaire (RPCSQ) (23) documented the presence and severity of commonly experienced symptoms following mTBI. The PAQ and the AC subscale both have two versions, one designed for children and one designed for use with adolescents.

The Physical Activity Questionnaire for Older Children (PAQ-C) and the Physical Activity Questionnaire for Adolescents (PAQ-A) (19-20) are self-administered 7-day recall questionnaires ascertaining the amount of habitual moderate to vigorous physical activity practiced in the seven days preceding the evaluation. Both are quick to administer, inexpensive and easy to understand.

Nine items for the PAQ-C and eight items for the PAQ-A, scored on a 5-point scale, provide a total activity score (mean of the 8 or 9 items). The tools also include a non-exhaustive list of activities and reference guides such as the day of the week and the time of day to reduce recall bias. For example, children are asked to rate how active they have been during their recess time at school over the last 7 days. A score of 1 is used when children recall that they "sat around for most of the time" and a score of 5 indicates that children "ran and played hard most of the time". Test-retest reliability of the PAQ-C is reported as very good with ICCs of 0.75 for boys and 0.82 for girls aged 8 to 13 years tested at one week intervals (19). Convergent validity with other measures such as the Seven-Day Recall Interview (24) or the Activity Rating Scale (14) was found to be acceptable (20,25). Evidence for construct validity was provided by examining the relationship with the athletic competence and behavioral conduct subscales of the Self-Perception Profile for children (21), where a positive correlation with the athletic competence subscale (r=0.48) and no significant relation with the behavioral subscale (r=0.16) were found (20-25).

Perceived athletic competence was assessed using the Athletic Competence (AC) subscale of the Self-Perception Profile for Children and for Adolescents (21-22). The Self-Perception Profile is a self-administered questionnaire consisting of five subscales covering domains from social competence to global self-worth. Each of the subscales can be used separately and only the AC subscale was used for this study. The internal consistency of the AC subscale was reported as ranging from 0.80 to 0.86 (Cronbach's alpha) (21). The AC subscale contains 6 items scored with a 4-point scale, where 1 represents a low level and 4 a high level of perceived competence. Children are asked to choose the statement that best applies to them: "some kids do very well at all kinds of sports" or "other kids don't feel that they are very good when it comes to sports". They then decide if the statement they have chosen is "sort of true" or "really true" for them. The mean of the scores on the 6 items is calculated to obtain a total score.

The Rivermead Post-Concussion Symptoms Questionnaire (RPCSQ) (23) was also administered in order to document the presence and more importantly the severity of 16 commonly experienced symptoms following mTBI. Their presence and severity are rated as compared to "usual levels" since the symptoms can be reported by non-injured individuals. The questionnaire is self-administered and the children are asked to rate the severity of the symptoms using values from 0 (to indicate the absence of the symptom) to 4 (referring to a severe problem). The scores for each of the 16 symptoms are combined to provide a total score. Apart from this study, the questionnaire has not been used with children but test-retest reliability of the RPCSQ was reported as high (R_S=0.91) (23) for a group of mTBI adults tested at a 24 hour interval. This result should, however, be interpreted with caution as no ICC values are available for this group.

In addition to the main outcome measures, the following information regarding the injury was obtained from the child's medical file: Glasgow Coma Scale score upon admission, concussion grade, duration of post-traumatic amnesia, duration of loss of consciousness, cause of injury, site of impact and initial symptoms.

Procedure

Children meeting the study criteria and their parents were told about the research on the day of admission to the trauma program. Those interested in participating were met on the same day by the study coordinator and premorbid measures of self-efficacy, physical activity level, perceived athletic competence were documented. It is unlikely that the presence of post-traumatic amnesia could have affected recall with regards to these measures since, as shown in table 1, only one child had post-traumatic amnesia lasting more than 60 minutes and even for him, it was resolved before the administration of the questionnaires. Children completed the same questionnaires a second time 12 weeks post-injury. As part of a larger study, the same sample of children were also assessed at 1, 4 and 12 weeks post-injury to document post-concussion symptoms as well as to evaluate their performance on various balance and visuo-motor response time tools. These results are presented elsewhere (4-5). The control group children were assessed at corresponding time intervals. All evaluations took place at the bedside or in the children's homes to minimize travelling inconvenience and school absenteeism. The assessment times were chosen because of their importance to children's recovery. For example, the initial assessment was meant to capture the child's pre-morbid status and was done as early as possible after the injury. At the second assessment, 12 weeks later, the children had been active in their physical activities for at least eight weeks given that the activity restriction period imposed on the child usually ends four weeks after the injury (1). As well, 12 weeks is the time when most post-concussion symptoms are resolved (26). The 12-week evaluations were done by an experienced pediatric physical therapist who, to the best of our ability and for most of the children, was blind to group status. The study received scientific and ethical approval from the Institutional Review Board of the Montreal Children's Hospital, McGill University Health Center. All children and their parents signed informed consent forms prior to data collection.

Data analysis

Scores were computed for each child on the following tools: the Self-efficacy questionnaire for the "mTBI related problems" dimension (possible scores ranging from 80-800) and "athletic skills" dimension (100-1000), the Physical Activity Questionnaire (1-5), the Athletic Competence subscale (1-4) and the Rivermead Post-Concussion Symptoms Questionnaire (0-64).

To address the study objectives, the test performances of the mTBI children were compared to those of the children in the control group using two-way ANOVAs (group and time) with repeated measures on the time factor. Greenhouse Geiser corrections were used for all ANOVA results when the distribution of the variables departed from normality. Differences between groups at each time were determined using independent t-tests and the specific time effect for each group was determined using paired t-tests. At each assessment time, relations between the injured children's performances on the tests were explored using Pearson correlations. The SPSS statistical package, version 10.0, was used for all analysis (27).

Results

Subjects

The characteristics of the mTBI group, presented in table 1, are consistent with those reported in the literature with boys representing 2/3 of the sample, falls being the most frequent etiology and headaches and nausea-vomiting being the most frequent initial symptoms present. The high average admission GCS as well as the presence of post-traumatic amnesia of more than 60 minutes in only one child illustrate the very mild nature of the TBI sustained by the children. Fiftynine percent of children sustained a mTBI that could be classified as a grade 2 concussion and 41 percent sustained a grade 3 concussion as per American Academy of Neurology practice parameters (28). The mTBI children described themselves as slightly more active than children their own age and sex (Activity Rating Scale 3.6 ± 0.9) and the control children were matched accordingly (Activity Rating Scale 3.7 ± 0.8). The children with mTBI had a mean age of 12.0 ± 2.9 years, while the controls had a mean age of 11.8 ± 2.9 years.

Both the level of participation in physical activities and the level of perceived athletic competence were similar between the groups initially and at the 12-week evaluation, and both groups essentially did not change over time. This was confirmed by the ANOVA performed on data for the PAQ (figure 1a) and for the AC subscale (figure 1b). Specifically, there were no differences found between the two groups, there was no time effect nor any interaction. Moreover, initial and 12 weeks PAQ scores were moderately correlated with each other ($r=0.60$; $p<0.001$ for mTBI; $r=0.57$; $p=0.002$ for the control group) as were the initial and 12 weeks AC subscale scores ($r=0.73$; $p<0.001$ for mTBI; $r=0.56$; $p=0.002$ for control group). Correlations between initial PAQ and initial AC subscale scores approached significance ($r=0.33$; $p=0.07$), but correlations between the 12-week PAQ and the 12-week AC subscale scores were not significant. No significant correlations were found between the PAQ and post-concussion scores (measured with the RPCSQ) nor between the AC subscale and post-concussion scores.

The results for the self-efficacy questionnaire for both dimensions are presented in figures 2a and 2b, respectively. Both groups of children had similar self-efficacy levels at the initial evaluation and only the injured children demonstrated decreased self-efficacy at 12 weeks. Specifically, the ANOVA performed on the "mTBI related problems" dimension (figure 2a) revealed no significant differences between the groups across testing sessions. However, there was a main effect for the time factor (repeated measure) ($F=16.32$; $p<0.001$), and a group x time interaction was found for the performances of the injured and non-injured children ($F=28.80$; $p<0.001$). The mTBI children demonstrated decreased self-efficacy compared to the control group at 12 weeks ($t=-3.34$; $p=0.001$) but not at the initial assessment ($t=1.09$; $p=0.281$). When the groups were taken separately, the time effect was only present for the mTBI group ($t=4.96$; $p<0.001$) as the injured children presented with lower scores in the 12th week when compared to the initial assessment.

The ANOVA performed on the "athletic skills" dimension (figure 2b) revealed no significant differences between the groups across testing sessions. Although, there was no main effect for the time factor (repeated measure), a group x time interaction was found for the performances of the injured and non-injured children (F=7.17;p=0.009). The mTBI children performed worse than those non-injured at 12 weeks post-injury (t=-2.26; p=0.03) but not at the initial assessment (t=-0.22; p=0.825). When the groups were taken separately, the time effect was present only for the mTBI group where children presented with lower scores in the 12th week when compared to the initial assessment (t=2.08; p=0.04). In summary, children with mTBI who felt as confident as their control friends at the initial assessment demonstrated a decrease in their level of confidence as identified in both dimensions of the self-efficacy questionnaire.

As for post-concussion symptoms (figure 3), there was a strong between group effect across all testing sessions (F=20.46; p<0.001). The mTBI children reported a significantly greater number of symptoms than the control group at all testing times (1, 4 and 12 weeks) with as many as 13% and 16% of children at 12 weeks reporting problems of fatigue and headaches respectively. There was a main effect for the time factor (F=11.14; p<0.001) (repeated measure) and there was a group x time interaction (F=25.40; p<0.001) for the performances of both groups. Specifically, there was a strong time effect (F=20.59; p<0.001) where the mTBI children improved between weeks 1 and 12 (p<0.001), between weeks 1 and 4 (p=0.002) and between weeks 4 and 12 (p=0.002). On the other hand, there was a time effect for the control group that just reached significance (F=3.35; p=0.04) with children reporting slightly lower post-concussion scores at 4 weeks than at 1 week (p=0.01).

Pearson correlations were performed with the data of the injured children to explore the relations between their self-efficacy levels and their level of participation in physical activities, their level of perceived athletic competence and reported post-concussion symptoms at all assessment times (table 2). The initial scores of both dimensions of the self-efficacy questionnaire were moderately correlated to the corresponding scores of the same dimension at 12 weeks (r=0.56 for the "mTBI related problems"; r=0.58 for the "athletic skills"). The scores for these two dimensions were moderately correlated with each other at 12 weeks (r=0.51) but not initially, showing some effect of the injury on both dimensions. Moreover the initial scores of the "athletic skills" dimension were weakly correlated to the scores of the "mTBI related problems" dimension at 12 weeks (r=0.47). Weak to moderate negative correlations were found between the 12-week scores on both self-efficacy dimensions and post-concussion scores (RPCSQ) at 4 and 12 weeks post-injury (r ranging from –0.43 to –0.65). In addition, the "athletic skills" dimension scores at 12 weeks were negatively related to the RPCSQ scores at 1 week post-injury. The 12-week scores of the "athletic skills" dimension were weakly correlated to the PAQ (r=0.37; p=0.03) and AC subscale (r=0.47; p=0.005) scores at 12 weeks, but not to scores from the initial assessment.

Discussion

The overall findings of this study are that children, three months following a mTBI, return to their premorbid level of physical activities and continue to perceive themselves as competent in their athletic abilities. However, despite having returned to their regular physical activities, a substantial number of children experience decreased self-efficacy with regards to their performance in these activities, 12 weeks after the injury.

Children with mTBI demonstrated similar levels of pre and post-injury participation in physical activities (PAQ scores) and perceived athletic competence (AC subscale) as those of the control group. The comparability of the two groups at the initial assessment in terms of participation level reflects the success of the matching procedure. The fact that both groups maintained their physical activity level three months later is an illustration of the stability of the measure of physical activity participation. Clearly, having sustained a mTBI does not appear to affect the level of participation in physical activities nor perceived athletic competence.

Children with mTBI had decreased levels of self-efficacy in both dimensions ("mTBI related problems" and "athletic skills") 12 weeks after the injury as compared to premorbid levels and as compared to the control group. One plausible explanation for these findings relates to the theory of self-efficacy. Self-efficacy is a concept that is situation-specific and related to one's confidence in the ability to produce expected results. Past performances, emotional and physical state when practicing physical activities as well as the observation of others and encouragement from others are information sources used to construct one's judgements of self-efficacy. Only the first two sources can however be addressed in the context of our study.

First, the children assessed 12 weeks post-injury had been involved in physical activities for the last 8 weeks (return to physical activities allowed at 4 weeks) and may have used the information generated by their performances throughout that period to influence their feelings of self-efficacy. If their performances were less optimal than prior to the injury, the judgements of self-efficacy derived from these performances could have been affected. The same sample of children did in fact present with balance deficits lasting up to 12 weeks post-injury (4) and perhaps the balance difficulties may have hindered their performances in their physical activities. As well, the presence of post-concussion symptoms such as fatigue and headaches in a substantial number of injured children (fig 3) may have impaired the children's emotional and physical state when engaging in physical activities, consequently affecting their self-efficacy. Indeed, the scores on both dimensions of the self-efficacy questionnaire were moderately correlated to PCS scores at 4 and 12 weeks post-injury, when children returned to physical activities.

At 12 weeks, weak but significant correlations were found between the scores of the "athletic skills" dimension of the self-efficacy questionnaire and the PAQ scores, and between the "athletic skills" dimension scores and the AC subscale scores while initially, these relations were not found to be significant. Interestingly, no such relations could be observed for the "mTBI related problems" dimension of the self-efficacy questionnaire with the PAQ or with the AC subscale initially or at 12 weeks post-injury. The "athletic skills" dimension, by referring to notions such as "being happy with one's performance" or "being confident to be picked first when making up teams" is somewhat more linked to the participation and athletic competence concepts than the "mTBI related problems" dimension that refers to specific problems encountered after a mTBI. The correlations observed after the injury between the "athletic skills" dimension and the PAQ and the AC subscale would appear to support the choice of separating the self-efficacy questionnaire into two dimensions.

The decision to separate the self-efficacy questionnaire into two separate dimensions is further supported by the moderate correlation found between the two dimensions at 12 weeks post-injury.

This indicates an association between the two dimensions in terms of the construct measured (self-efficacy related to physical activities post-mTBI) but enough distinctness related to each dimension to prevent a very high correlation between the two. The absence of correlation between the two dimensions at the initial assessment (reflecting the pre-morbid status of the children) could be attributed to the fact that the children all presented with very high self-efficacy scores. One could argue that the ceiling effect of the measure at the initial assessment may have limited the correlation analysis. However, this absence of correlation could also be attributed by the questionable validity of measuring the "mTBI related problems" dimension of self-efficacy prior to the actual injury. In fact, at 12 weeks, when the measure of this dimension becomes relevant, a clear relation between the dimensions exists.

The results concerning a decrease in self-efficacy following a mTBI should be considered with some caution. First, although the self-efficacy questionnaire was developed according to standard procedures, it was used here for the first time before formally assessing its psychometric properties. This new tool however appears promising in that it demonstrated stability over time for the control group and was able to detect differences between groups at 12 weeks. Second, the decrease in self-efficacy levels in the mTBI group could not only be attributed strictly to the fact that these children had sustained an injury but perhaps also to the fact that they had been restricted from their physical activities restrictions for four weeks. Ideally, to control for this bias, the control group should also have consisted of injured children (without a mTBI) with similar activity restrictions. This, however, was not possible since these results were obtained in the context of a larger study also examining balance and visuo-motor response times at 1, 4 and 12 weeks post-injury. Clearly, orthopedic injuries may have affected the balance and response time evaluations of the control group thus limiting our interpretations about possible balance and response time deficits following mTBI. Finally, one cannot conclude that a decrease in self-efficacy directly affects performance since we did not evaluate the actual performance of the children during their various physical activities.

In conclusion, although the mTBI children had returned to their pre-injury level of PA and had maintained their athletic competence trait, they did not feel as confident in their ability to perform their activities at 12 weeks post-injury as compared to how they felt before their injury. Because of the chosen study design and assessment times, it remains unclear as to how the children's self-efficacy level evolved during the 12-week period. As well, it is unclear what happens to the levels of self-efficacy beyond this time. Hopefully, the self-efficacy levels return to pre-morbid levels gradually over the months that follow as children rebuild their confidence. Nevertheless, these remain important preliminary findings that warrant further investigation. This is especially true with regards to possible interventions strategies targeting children and their parents that could potentially minimize the impact of the mTBI on children's confidence in their performance in physical activities.

AKNOWLEDGMENTS

The authors wish to acknowledge the financial support of the Fondation Marie Robert pour la recherche sur les traumatisés crâniens, Réseau provincial de recherche en adaptation-réadaptation (REPAR), Ordre professionnel des physiothérapeutes du Québec and the Physiotherapy Foundation of Canada.

We also wish to thank the children and their families for their participation in this research.

REFERENCES

1. Swaine BR, Friedman DS. Activity restrictions as part of the discharge management for children with a traumatic brain injury. J Head Trauma Rehab 2001; 16: 292-301.

2. Gagnon I, Forget R, Sullivan SJ, Friedman D. Motor performance following a mild traumatic brain injury in children: an exploratory study. Brain Injury 1998; 12: 843-853.

3. Gagnon I, Friedman D, Swaine B, Forget R. Balance findings in a child before and after a mild head injury. J Head Trauma Rehab 2001; 16: 595-602.

4. Gagnon I, Forget R, Swaine B, Friedman D. Balance findings after a mild head injury in children. Neurorehabilitation and Neural Repair. 2002; 16: 22-23.

5. Gagnon I, Swaine B, Friedman D, Forget R. Transient increase in response time after a mild head injury in children. Arch Phys Med Rehab 2002; 83: 1481

6. Bandura A. Social foundations of thought and action: a social cognitive theory. Englewood Cliffs, NJ: Prentice Hall, 1986, p.391.

7. Bandura A. Perceived self-efficacy in the exercise of personal agency. Appl Sport Psychol 1990; 2: 128-63.

8. Dilorio C, Faherty B, Manteuffel B. The development and testing of an instrument to measure self efficacy in individuals with epilepsy. J Neuroscience nursing 1992; 24: 9-13.

9. Maibach E, Murphy DA. Self-efficacy in health promotion research and practice: conceptualization and measurement. Health Education Research 1995; 10: 37-50.

10. Kilgore JM. An investigation of the effects of short-term injuries on psychological readiness for competition. Microform publications, University of Oregon Eugene, Or., 1998.

11. Harter, S.: The Perceived Competence Scale for Children. Child Development, 53: 87-97, 1982.

12. Harter S, Connell JP. A model of children's achievement and related self-perceptions of competence, control and motivational orientation. Advances in Motivation and Achievement 1984; 3: 219-250.

13. Mild Traumatic Brain Injury committee (American Congress of Rehabilitation Medecine, Head Injury Interdisciplinary Special Interest Group): J Head Trauma Rehab 1993; 8: 86-87.

14. Sallis JF, Patterson TL, Buono MJ, Nader PR. Relation of cardiovascular fitness and physical activity to cardiovascular disease risk factors in children and adults. AmJ Epidemiology 1988; 127: 933-941.

15. Sallis JF, Buono MJ, Roby JJ, Micale FG, Nelson JA. Seven-day recall and other physical activity self-reports in children and adolescents. Med Sci Sports Exerc. 1993; 25: 99-108.

16. Lorig K, Chastain RL, Ung E, Shoor S, Holman HR. Development and evaluation of a scale to measure self-efficacy in people with arthritis. Arthritis Rheum 1989; 32: 37-44.

17. Schwatz CE, coulthard-Morris L, Zeng Q, Retzlaff P. Measuring self-efficacy in people with multiple sclerosis: a validation study. Arch Phys Med Rehab 1996; 77: 394-98.

18. Streiner D, Norman G. Health Measurement Scales: A practical guide to their development and use. New York, New York: Oxford Medical Publications,1989.

19. Crocker, P.R.E., Bailey, D.A., Faulkner, R.A., Kowalsky, K., McGrath, R.: Measuring general levels of physical activity: preliminary evidence for the physical activity questionnaire for older children. Med Sci Sports Exercise 29: 1344-1349, 1997.

20. Kowalsky, K.C., Crocker, P.R.E., Kowalsky, N.P.: Convergent validity of the physical Activity Questionnaire for Adoloescents. Pediatric Exercise Sci 9: 342-352, 1997.

21. Harter S, Manual for the Self-Perception Profile for Children (Revision of the Perceived Competence Scale for Children). Denver, CO: University of Denver, 1985.

22. Harter S, Manual for the Self-Perception Profile for Adolescents. Denver, CO: University of Denver, 1988.

23. King NS, Crawford S, Wenden FJ, Moss NE, Wade DT. The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. J Neurol 1995; 242: 587-92.

24. Sallis JF, Haskell WL, Wood PD, Fortmann SP, Rogers T, Blair SN, Paffenbarger RS. Physical activity assessment in the five-city project. Am J Epidemiol 1985; 121: 91-106.

25. Kowalsky, K.C., Crocker, P.R.E., Faulkner, R.A.: validation of the Physical Activity Questionnaire for Older Children. Pediatric Exercise Science 9: 174-186, 1997.

26. Levin HS, Outcome from mild head injury. In: Narayan RK, Wilberger JE, Povlishock JT, editors. Neurotrauma. McGraw Hill Cies inc, 1996.

27. Supplier of SPSS: SPSS® Base 10.0. SPSS Inc., 233 South Wacker Drive, 11th Floor, Chicago, IL, 60606-6307.

28. American Academy of Neurology. Report from the Quality Standards Subcommittee. Practice parameter: The management of concussion in sports (summary statement). Neurology 1997; 48: 581-585.

Table 1: Characteristics of the mTBI children

Characteristics		**Frequency**	**Percentage**
Gender	Male	24	71
	Female	10	29
Cause of injury	Falls	16	47
	Bicycle falls	7	20
	MVA-ped	1	3
	MVA	1	3
	Other (hits,etc...)	6	18
	missing	3	9
Site of impact	Posterior	14	41
	Left	9	26
	Anterior	6	18
	Right	4	12
	Missing	1	3
Admission GCS	13	1	3
	14	6	18
	15	27	79
Duration of LOC	No LOC	20	59
	0-10 minutes	12	35
	>10 minutes	2	6
Duration PTA	0-60 minutes	33	97
	>60 minutes	1	3
Concussion grade	1	0	0
	2	20	59
	3	14	41
Initial symptoms	Headache	28	82
	Nausea-vomitting	22	65
	Dizziness	14	41
	Visual problems	6	18
	Drowsiness	11	32
	Auditory problems	1	3

GCS: Glasgow Coma Scale; LOC: loss of consciousness; MVA: motor vehicle accident; PTA: post-traumatic amnesia

Table 2: Pearson correlations between the self-efficacy questionnaire scores and other variables

		Self-efficacy initial		**Self-efficacy 12 weeks**	
Self-efficacy initial		MTBI related problems	Athletic skills	MTBI related problems	Athletic skills
MTBI related problems	Coefficient	1.000			
	p-value				
Athletic skills	Coefficient	0.150	1.000		
	p-value	0.413			
Self-efficacy 12 weeks					
MTBI related problems	Coefficient	0.562	0.474	1.000	
	p-value	**0.001**	**0.006**		
Athletic skills	Coefficient	-0.071	0.578	0.512	1.000
	p-value	0.701	**0.001**	**0.002**	
PAQ initial	Coefficient	0.099	0.102	0.209	0.141
	p-value	0.595	0.586	0.259	0.448
PAQ 12 weeks	Coefficient	0.039	0.030	0.181	0.347
	p-value	0.834	0.872	0.305	**0.044**
AC initial	Coefficient	0.043	0.158	0.067	0.279
	p-value	0.817	0.395	0.722	0.129
AC 12 weeks	Coefficient	0.054	0.320	0.049	0.399
	p-value	0.771	0.079	0.785	**0.022**
RPCSQ 1 week	Coefficient	0.293	-0.161	-0.282	-0.360
	p-value	0.104	0.377	0.106	**0.036**
RPCSQ 4 weeks	Coefficient	0.192	-0.280	-0.434	-0.508
	p-value	0.302	0.127	**0.012**	**0.003**
RPCSQ 12 weeks	Coefficient	0.113	-0.230	-0.499	-0.652
	p-value	0.553	0.222	**0.004**	**0.000**

MTBI: Mild traumatic brain injury; PAQ: Physical Activity Questionnaire; AC: Athletic Competence; RPCSQ: Rivermead Post-Concussion Symptoms Questionnaire.

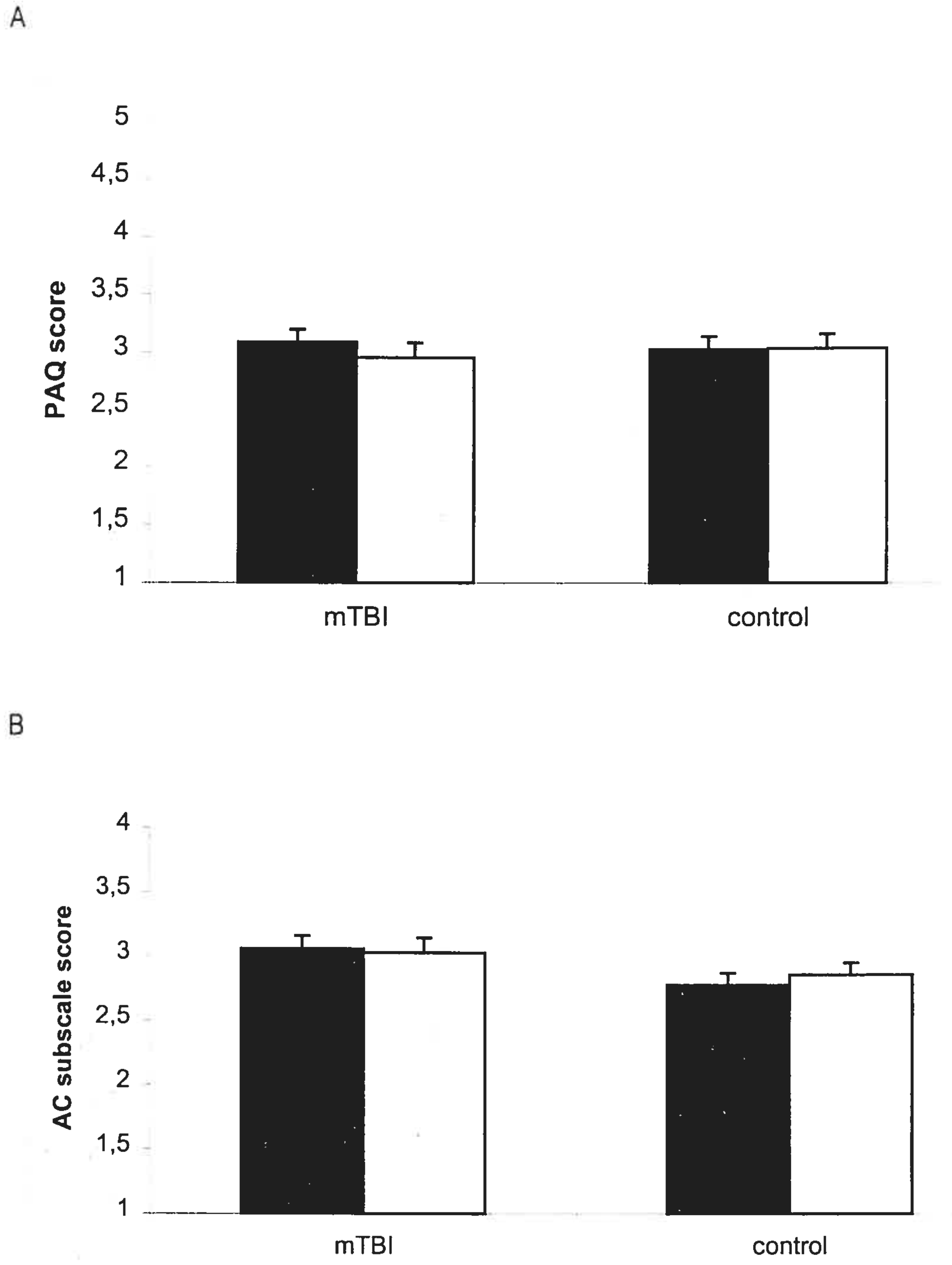


Figure 1: Level of participation in physical activities as measured by the Physical Activity Questionnaire (A) and perceived athletic competence as measured by the Athletic Competence subscale of the Self-Perception Profile (B) for both groups of children. Represented are the mean and standard error of the mean at the initial (■) and 12-week (□) assessments

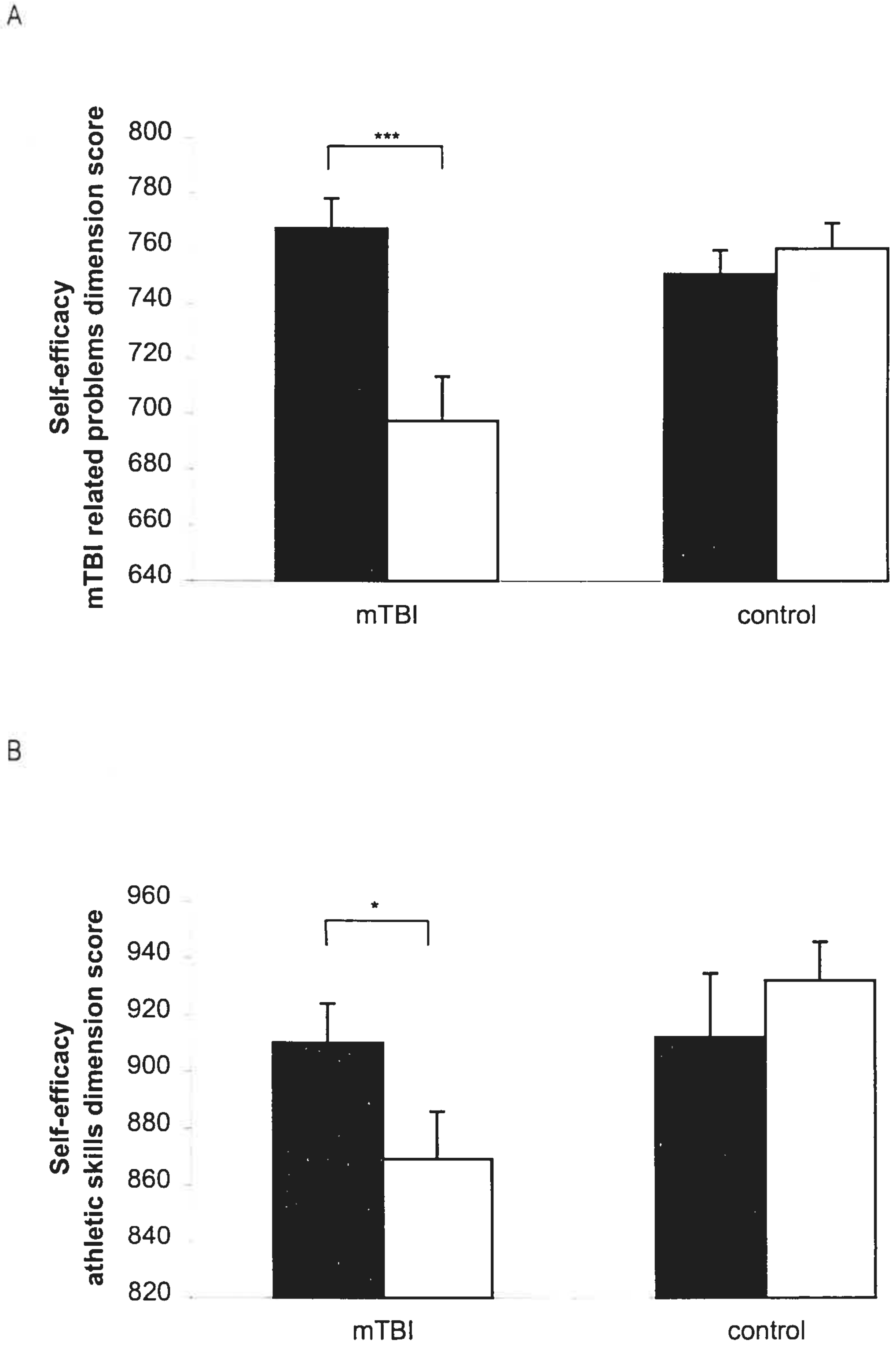


Figure 2: Self-efficacy related to physical activities as measured by the "mTBI related problems" dimension (A) and the "athletic skills" dimension (B) of the self-efficacy questionnaire for both groups of children. Represented are the mean and standard error of the mean at the initial (■) and 12-week (□) assessments ***: p<0.001; *: p<0.05.

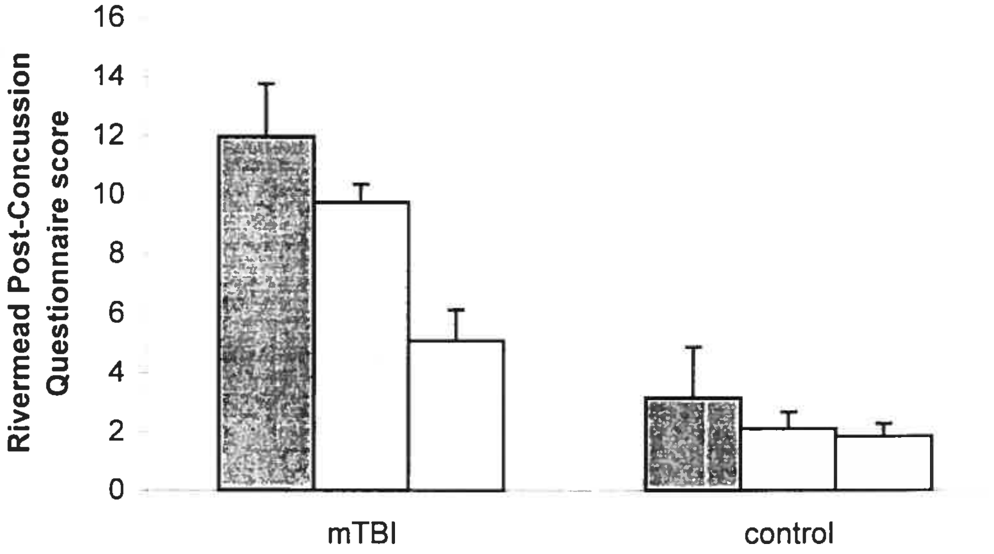


Figure 3: Presence and severity of the post-concussion symptoms as measured by the Rivermead Post-Concussion Symptoms Questionnaire for both groups of children. Represented are the mean and standard error of the mean at the. ▨ :1-week assessment, ⊡ :4-week assessment, □ :12-week assessment, ***: p<0.001; **: p<0.01; *: p<0.05.

4.4 Comparaison entre les outils l'évaluation de l'interaction sensorielle pour l'équilibre

4.4.1 Article 5: Comparing the Sensory Organization Test and the Pediatric Clinical Test of Sensory Interaction for Balance in children

Gagnon I, Swaine B, Forget R. Comparing the Sensory Organization Test and the Pediatric Clinical Test of Sensory Interaction for Balance in children. *Physical Therapy* (soumis)

This research was supported in the form of a grant by:
Fondation Marie Robert pour la Recherche sur les Traumatisés Crâniens

Keywords: Balance, children, adolescents, sensory organization,

Part of this manuscript was presented at the 14th World Congress of Physical Therapy, Barcelone, Espagne, Juin 2003.

The study received scientific and ethical approval from the Institutional Review Board of the Montreal Children's Hospital, McGill University Health Center, Montreal, Canada.

ABSTRACT

BACKGROUND AND PURPOSE: The Sensory Organization Test (SOT) and the Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB) quantify the ability to maintain balance in the presence of sensory conflicts. The purposes were to compare the performance of healthy children on these two assessments and examine the relationship between age and assessment performances. SUBJECTS: Sixteen healthy children (9.8 ± 3.5yr.). METHODS: Children were assessed with both tools during a single session. RESULTS: Only three conditions of the SOT were related to the corresponding PCTSIB conditions: eyes closed in tandem and single leg stance (SLS), and altered vision in SLS. None of the conditions involving altered support surfaces were related. All SOT conditions and four PCTSIB conditions only in SLS, were significantly related to age. DISCUSSION AND CONCLUSION: Although both tests are associated with age, they do not measure sensory organization abilities in the same manner. As such, they each provide different and complementary information about healthy children's ability to maintain balance.

Introduction

Balance is an essential prerequisite of most activities of daily living in children. It can be broadly defined as a condition where all forces and torques acting on the body are in equilibrium so that the individual's centre of mass is within the individual's limits of stability[1-4]. Postural control is the means by which balance is achieved with the purpose of controlling the relation between the center of mass and the individual's base of support. To maintain a position or ensure appropriate transitions between positions, the nervous system must rapidly integrate incoming sensory information from various sources, then use this information to generate complex motor responses, adapted in their timing sequence and amplitude to the characteristics of the situation, to particular environmental constraints and to external and internal perturbations of the body.

It is generally recognized that three main sources of sensory information contribute to effective postural control: visual, proprioceptive and vestibular. The eyes register the movements of objects in the environment as well as the individual's movements within this environment. The proprioceptive input from the muscle spindles, tendon organs, joint and tactile receptors provides information about the movement speed and muscle forces generated, the position of the body segments in relation to one another and the individual's support surface. Finally, the vestibular system is the body's internal reference that provides information about the individual's head position and movements in relation to gravity. In the context of balance, sensory organization is usually defined as an individual's ability to integrate sensory input and identify, among redundant sensory information, the most accurate and appropriate input for the maintenance of balance. In children, this ability is dependent on the integrity of the sensory systems and of the CNS, and varies as a function of a child's age and developmental level[5]. For example, among children between 4 months and 2 years old, the visual system is usually predominant in providing input to maintain balance. Between the ages of 3 to 6 years, subsequent maturation of the CNS allows children to use somatosensory information. Finally, between the ages of 7 to 10 years a child's vestibular system has the capacity for conflict resolution[6-7].

In reaction to external perturbations or in anticipation of voluntary movements, children, like adults, exert postural control using specific sequences of muscle activation (i.e. ankle, hip, stepping strategies). These strategies are also subject to the maturation and development of the systems involved. Numerous studies have demonstrated that they are present as early as the age of 18 months and evolve in terms of timing and amplitude over the next several years[8-9]. A transitional stage, where responses are less coordinated in terms of amplitude and timing, takes place between the ages of 4 to 6 years and the strategies appear to reach a mature stage, or become adult-like, by the ages of 7 to 10 years.

The assessment of balance is a core component of the pediatric rehabilitation specialist's evaluation. When the goal of the balance assessment in children is to address specifically the contribution and interaction of sensory systems to postural control and the ability to adapt to modified or conflicting sensory inputs, tools assessing the amplitude of postural sway or the ability to maintain balance in the presence of sensory conflicts are useful. Instrumented and standardized clinical assessment tools have been developed for this purpose. These include the Sensory Organization Test (SOT) of the Neurocom Smart Balance Master™[10] and the Clinical Test of Sensory Interaction for Balance (CTSIB)[11].

The SOT of the Neurocom Smart Balance Master™ is a platform posturography tool that was designed to study, among adults and children, the contribution of visual, proprioceptive and vestibular inputs in an individual's ability to maintain balance. In this test, sensory information is manipulated to reduce the amount of, or provide conflicting sensory information. The Clinical Test of Sensory Interaction for Balance was developed as an inexpensive clinical alternative to the SOT to address the same concepts and has been adapted for the pediatric population[12]. Both the SOT and the Pediatric-CTSIB (PCTSIB) were designed based on the same conceptual framework of balance control. The premise of this framework is that there is no single dominant source of sensory input, that sensory information is redundant, and that some form of dynamic weighing of sensory inputs may be necessary to optimize the control of postural stability[13]. Both assessment tools test sensory interaction by focussing on the child's ability to maintain standing positions while receiving various sensory perturbations in six sensory conditions that should theoretically correspond to one another. Being portable, affordable and easy to administer, the PCTSIB has gained popularity in the clinical settings unable to afford platform posturography. However, it is unclear whether the SOT and the PCTSIB measure the same or different aspects of balance due to the differences in equipment and modalities assessed. In fact, the relationship between the two tools has not yet been established in children. The purpose of this study was therefore to compare the performances of healthy children on these two assessment tools of standing balance; that obtained using the SOT and that obtained using the PCTSIB. Based on the assumption that the PCTSIB is a clinical alternative to the SOT, we hypothesized that the children's performances on corresponding conditions of both tests should be strongly correlated. In addition, if the six sensory conditions purport to test varying levels of complexity of sensory interaction, one would expect that the performances across conditions within both tests should be ranked in the same order. A secondary objective of the study was to examine the relationship between age and performance on the two assessment tools.

Methods

Subjects

A convenience sample of 16 healthy children aged between 5 and 16 years (9.75 yr. ± 3.47 yr.) was recruited for this study. The subjects were the children of the first author's colleagues and friends. Children were excluded if they had a neurological or orthopedic condition affecting balance, if they were not in the school grade expected for their age or if their parents reported general problems in physical activities such as having been flagged by the physical education teacher as having difficulties or as not performing as well as expected in sports. All children and their parents signed an informed consent form prior to data collection and the study received scientific and ethical approval.

Measures

The Sensory Organization Test (SOT) of the Neurocom smart Balance Master™* and the Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB) are described below.

---

* NeuroCom International Inc., Clackamas, OR 97015

The SOT is a tool designed to study visual, proprioceptive and vestibular inputs, and their specific role in an individual's ability to maintain balance. The test requires the individual to stand quietly on two force plates that are computer controlled to allow movement of the support surface in phase with the amplitude of postural sway. The support surface is surrounded by a three-sided movable wall that similarly allows movement in phase with postural sway. The amplitude of the child's postural sway is measured while standing in bilateral stance for 20 seconds in six different sensory conditions that are described in table 1. As determined by the test procedure, sway is calculated from the maximum anterior and-posterior center of gravity displacements over the testing period. To obtain a "stability score", the calculated sway is compared to the subject's theoretical limits of stability. These limits of stability are assumed to be a range of 6.25° anteriorly, 4.45° posteriorly and 8.00° to both sides of the center of the feet support and represent the area in which the individual can move without changing the base of support. The stability score is expressed as a percentage, with 100% representing perfect stability and 0% indicating sway exceeding the limits of stability. Several of the psychometric properties of the SOT have been well established. Test-retest reliability has been established as good (Cronbach's alpha ≥ 0.58) with healthy children ranging in age groups from 5 to 15 years[14-15]. The SOT is able to differentiate between the stability scores of children of different age groups (developmental progression)[15-16] and between children with and without pathologies such as learning disabilities[17-18], hearing impariments[19], cerebral palsy[20-21], Down syndrome[22] or prematurity[23] in terms of their use of strategies in response to sensory organization challenges. Indeed, the SOT provides a stable and useful measure of children's ability to use their sensory systems and how this ability relates to the maturation of the CNS.

The Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB) is a version of the Clinical Test of Sensory Interaction for Balance adapted for children. Both versions use the same equipment consisting of a medium density foam support surface, believed to alter the nature of the proprioceptive input, and a visual conflict dome made from a Chinese lantern. The child is asked to stand quietly in bilateral and tandem stance and is tested in six different sensory conditions corresponding to those found in the SOT (table 1). Measures for each condition include the time spent in position without postural adjustments, up to a maximum of 30 seconds (holding time), and the measurement of antero-postural or lateral sway, using the child's nose as a reference. A summary score ranging from 0 to 5 is also calculated, combining both holding time and amplitude of sway for each condition (see below).

0 Child cannot assume the position
1 Child maintains stance 3 seconds or less
2 Child maintains stance 4 through 10 seconds
3 Child maintains stance 11 through 29 seconds, or 30 seconds with >15 degrees of sway
4 Child maintains stance 30 seconds with 6 through 15 degrees of sway
5 Child maintains stance 30 seconds with less than 6 degrees of sway

The psychometric properties of this assessment tool have been studied over the last decade. Interrater and test-retest reliability were tested with a group of 24 children, aged 4 to 9 years and without developmental problems, and reported to vary between 0.69 to 0.92 (Spearman *rho*)[12] and between 0.44 to 0.83 (Spearman *rho*)[24], respectively. No ICC's are however reported for the test. The PCTSIB has been used successfully to assess sensory organization in children with learning disabilities and cerebral palsy[25] differentiating them from children without pathologies. Richardson[26] reported preliminary norms for 40 children aged 4 and 5 and 82 children aged 6 to 9, and found no gender differences but an overall developmental progression in the test scores. Although more research needs to be done to further establish the psychometric properties of this tool, its affordability and ease of use allows clinicians to standardize their assessment of sensory interaction in balance.

Procedure

Data were collected during a single session at the Montreal Rehabilitation Institute where the instrumented tool (SOT) was available. Assessment sessions lasted around 30 minutes and rest periods were allowed if requested. The first author, an experienced pediatric physical therapist, performed all of the evaluations.

For the PCTSIB, children were asked to remove their shoes and stand quietly with hands on the waist for as long as possible, up to 30 seconds. To maximize the potential for variability among the subjects evaluated in the present study, children were assessed in tandem and single leg stance (SLS), but not in bilateral stance. A trial was terminated when the subject's arms or feet position changed indicating a postural adjustment or after the child had maintained the position for the maximum of 30 seconds. The PCTSIB assessment was always performed first and was videotaped for later reviewing to score antero-posterior sway amplitude. After the testing, a transparency with lines radiating in 1 degree increments was placed over the screen of the video monitor and allowed for the measurement of peak to peak sway. For the SOT, subjects were instructed to remove their shoes and to step onto the force plates at a position predetermined by the test protocol. The visual display monitor was adjusted to the child's eye level. Children were instructed not to move their feet and were asked to stand still with their arms at their sides throughout the testing procedure. Postural sway was measured over a 20-second period in the six different sensory conditions described in table 1.

Data Analysis

The following performance scores were obtained for each child: holding time and summary score categories for each condition and for both feet positions as part of the PCTSIB and percentage of the child's limits of stability in the SOT. The degree of difficulty of the foot positions within the PCTSIB was examined using paired t-tests between holding times for the conditions in tandem and SLS. In order to establish the level of sensory interaction complexity across conditions within each test, one way ANOVAs with repeated measures on the factor Condition were performed. Post-hoc differences across particular conditions were examined. The children's performances on the PCTSIB (holding time and summary score categories) were compared to those obtained on corresponding conditions of the SOT (stability score) using Spearman rank correlation coefficients. Spearman rank correlation coefficients were also calculated to examine the relationship between age and the children's performances on each assessment tool. The SPSS statistical package, version 10.0, was used for all statistical analyses[†].

Results

Descriptive statistics for the performances on the PCTSIB and SOT are presented in table 2. All children were able to assume the starting positions for all conditions on both assessment tools,

---

[†] SPSS Inc., 233 South Wacker Drive, 11th Floor, Chicago, IL, 60606-6307

although some conditions were maintained but only briefly. For the PCTSIB, mean holding times varied from 3.9 s. for condition 6 in single leg stance (SLS) to 29.4 s. for condition 1 in tandem. Most of the children maintained condition 1 for the maximum amount of time required (30s.) in both tandem and SLS. For the remaining conditions, the SLS position was more difficult than the tandem position ($p < 0.02$). However, for both foot positions, the level of sensory integration complexity across conditions was similar, as evident by the decreasing amount of time children could maintain a particular position. Only the performances during conditions involving absent or altered vision (condition 3, 5 and 6), were different from those in condition 1 ($p < 0.01$). Standing with eyes open on the foam (condition 4) was not different from standing on the floor (condition 1) ($p > 0.2$).

For the SOT, the best performances were observed for the conditions where the support surface was stable (e.g. conditions 1 to 3). The increasing level of sensory interaction complexity across conditions reflected by the decreasing stability across conditions (1 through 6) was however different from that found for the PCTSIB. For the SOT, conditions 4, 5 and 6 differed from condition 1 ($p < 0.001$) and all three involved the perturbation of the support surface with or without altering visual input.

Spearman rank correlations between the PCTSIB holding times and the SOT stability scores of the corresponding conditions are presented in table 3. Only three pairs of conditions were significantly related: condition 2 (eyes closed) in both tandem and SLS, and condition 3 (vision altered) in SLS, all of which involve standing on a stable support surface. No correlations were found between corresponding test performances for conditions 4 to 6, where the support surface was perturbed. Spearman rank order correlations between the PCTSIB summary score categories and the SOT stability scores are presented in table 4. These summary score categories reflect holding time and amplitude of sway while maintaining a position. Only condition 6 (vision altered-perturbed support surface) in tandem and condition 2 (eyes closed) in SLS were found to be significantly related between the two tools.

Correlations between the children's age and performance on the tests are presented in table 5. The performances for all SOT conditions were found to be significantly related to the child's age.

For the PCTSIB, holding time performances on only one tandem condition and on four of six SLS conditions were found to be significantly related to the child's age.

Discussion

The purpose of this study was to examine the relationship between children's performance on two measures of sensory organization for balance, one instrumented and one clinical, developed as an alternative to the former. We chose to first focus on healthy children because both tools are often used as screening tools with children who are considered healthy or present with only subtle balance problems. Our first hypothesis was that if both assessment tools purport to measure the same aspects of sensory interaction in balance, the performance of children on corresponding conditions of both tests and across conditions within each test would be closely related. Our results however revealed that performances across and within both tools are not consistently related.

Examination of mean performances for the PCTSIB revealed that SLS was more difficult than tandem for both holding times and summary scores in all conditions. This was especially evident in condition 2 where there is an absence of vision. Nevertheless, there was an increasing level of complexity of sensory interaction that was similar for holding time and summary score categories in these positions. In tandem and SLS, the easiest task was condition 1 followed by conditions 4, 2, 3, 5 and 6. The order of complexity was different for the SOT where the increasing difficulty was observed from conditions 1 through 6.

A relationship between corresponding conditions of the two assessment tools could not be found consistently across conditions. For PCTSIB holding times, only the conditions with eyes closed (condition 2) in both tandem and SLS, and those with vision altered (condition 3) in SLS were related to the corresponding conditions on the SOT. The related conditions involve standing on a firm surface of a similar nature, while manipulating visual input. On the other hand, the conditions involving the perturbed support surface were generally not correlated in the two assessment tools particularly with regards to holding time in the PCTSIB.

The nature of the proprioceptive perturbation imposed in both tools warrants some discussion. The perturbation of the support surface in the SOT appears to provide more disturbance than that of the foam surface in the PCTSIB. For the PCTSIB, when children are allowed to use vision, they are still able to maintain positions for almost the maximum time (30s.) whether on a stable (floor) or perturbed (foam) surface (condition 1 and 4, respectively). In other words, the foam does not appear to affect the children's performances in a significant manner when vision is present and unaltered. On the other hand, even in the presence of vision, stability is significantly decreased by perturbing the surface in the SOT (conditions 4 and 1). Clearly the alteration imposed by the foam surface used in the PCTSIB and the tilting surface of the SOT are intrinsically different. The support surface in the SOT is tilted as to maintain the subject's ankle at a 90° angle by matching real time ankle antero-posterior postural responses, potentially altering the proprioceptive information to a point of near elimination. The medium density foam used in the PCTSIB to achieve the alteration of the support surface does not appear to eliminate proprioceptive information but rather provides a constant alteration on the system in all planes, and thus provides altered or increased but not absent or decreased proprioceptive information. As such, the equipment used could explain the observed absence of relationship between the two tools for these conditions.

The introduction of altered visual input, achieved in the PCTSIB by using a dome and in the SOT by standing in a three-sided moveable enclosure, could also affect the comparability between the two tests. For both foot positions in the PCTSIB, the alteration of visual input achieved by the introduction of the dome significantly affects children's performance even when standing on a stable surface (condition 3 vs 1), which is not the case when altering vision using the visual enclosure in the SOT. Nevertheless, both the holding time and the summary score categories of the PCTSIB vision altered conditions (condition 3) were related to the corresponding condition of the SOT in SLS and a trend could be observed in tandem. While the dome is more perturbing than the visual enclosure, the relationship between the measures indicates that the two tests possibly address the same visual integration ability.

The nature of the variables measured may also in part explain the lack of correlation between the tests. The PCTSIB primarily measures time spent holding a position (holding time). The SOT stability scores are expressed exclusively in terms of percentage of limits of stability derived from sway measurements. An appreciation of sway is included only in the summary score of the PCTSIB and it combines the results for holding time and sway for each condition. Differences in the nature of these measurements likely introduce some discrepancy between the two tests, especially when the holding time scores of the PCTSIB are compared to the SOT stability scores. In fact, correlations involving summary score categories, because they take into account amplitude of sway, appear to be improved for some conditions and even became significant for condition 6 in tandem. Ideally it would have been better to compare two pure measures of sway if such data had been available, but a measure of sway could often not be recorded in the PCTSIB because children did not maintain positions long enough (> 3 seconds).

Finally, the different foot positions assumed by the children in each test could also be responsible for the lack of relationship between the two tools. This is however unlikely since one would expect to find absent or weak correlations in many conditions, which was not the case here. Although the SOT standard protocol requires the child to assume bilateral stance for the duration of testing, we tested the PCTSIB in tandem and SLS. Bilateral stance was not used in the PCTSIB for this study because research with younger children[24,27]; and with children of similar age as our sample[28] revealed a ceiling effect for both holding time (almost all children easily maintain 30 seconds in all conditions) and for the summary score categories. In other words it was too easy and the lack of variability would have prevented correlation analysis between the tools.

Our sample ranged in age from 5 to 16 years, providing variability to study the relationship between performance and age. All of the conditions of the SOT were related to the children's age, demonstrating its ability to identify the developmental progression associated with the acquisition of balance skills. In contrast, there was insufficient variability for some conditions of the PCTSIB to allow for an adequate analysis between performance and age for this test. For example, ceiling effects were observed for condition 1 in both tandem and SLS. On the other hand, a floor effect was observed for condition 6 in SLS since most children found it difficult to maintain this position. The PCTSIB was related to age for all other conditions in SLS. However, in tandem, only the vision altered-perturbed support surface condition which was the most difficult condition in this position was found to be related to age. Because of the inability of the tandem position of the

PCTSIB to ascertain the developmental progression of balance skills, the sensory conditions tested in this position probably are not useful with children without pathology except in the most difficult condition.

Testing in our study was done only with a small group of healthy subjects and thus the results may have limited generalizability. The observed performances on the PCTSIB are however comparable to that of a group of 38 healthy children of similar age tested as part of an earlier study[28]. Furthermore, as would be expected with the maturing of the neural structures involved in the maintenance of balance, our sample (mean age of 9.8 years) demonstrated longer holding times for the PCTSIB as compared to those previously published for the PCTSIB tandem position with young children (4-5 years old)[26]. The observed performances on the stability scores for all conditions of the SOT are also comparable to those children of similar ages[15-16]. The comparability of the present results with those of others lends support to the generalizability of our results despite the relatively small sample size.

Conclusion

This study has shown that although the two sensory integration assessment tools both investigate children's ability to maintain postural stability in the presence of sensory conditions of various nature and complexity, they do not appear to assess sensory information integration in the same manner. First, with regards to how the vision altered condition is achieved, the dome in the PCTSIB appears to impose more perturbation on the visual system than the visual enclosure in the SOT. Moreover, the perturbation of the proprioceptive input is achieved to a higher degree by the moving platform of the SOT when compared to the foam surface used in the PCTSIB. In fact, it is only when vision is removed or altered that the foam is found to significantly alter stability in our group of children. The children's performance in the conditions involving the perturbation of the support surface is not related between the two tools. Finally, since the tandem position of the PCTSIB is not related to the child's age for most conditions, we recommend that testing be conducted in SLS with the PCTSIB or in bilateral stance using the SOT when screening for sensory interaction difficulties as a function of age. To summarize, clinicians should be aware that the PCTSIB does not appear to be a "clinical alternative" to the SOT but that it nevertheless provides an easy and inexpensive way of addressing sensory interaction in children.

REFERENCES

1. Horak FB. Clinical measurement of postural control in adults. Phys Ther 1987; 67: 1881-1884.

2. Reed ES. Changing theories of postural development. In Woollacott, M.H., Shumway-Cook, A. (eds). Development of posture and gait across the life span, Columbia SC: University of South Carolina Press, 1989.

3. Woollacott MH, Shumway-Cook A. Concepts and methods for assessing postural instability. J Aging Phys Activity 1996; 4: 214-233.

4. Horak FB, Henry SM, Shumway-Cook A. Postural perturbation, new insights for the treatment of balance disorders. Phys Ther 1997; 77: 517-533

5. Westcott SL, Lowes LP, Richardson PK. Evaluation of postural stability in children: current theories and assessment tools. Phys Ther 1997; 77: 629-645.

6. Shumway-Cook, A., Woollacott, M.: Dynamics of Postural Control in the child with Down Syndrome. Phys Ther 65:1315-1321, 1985.

7. Woollacott MH, Shumway-Cook A, Williams HG. The development of posture and balance control in children. In: Woollacott MH, Shumway-Cook A, eds. Development of posture and gait across the life span. Columbia, SC: University of South Carolina Press: 1989: 77-96.

8. Horak FB, Nashner LM. Central programming of postural movements: adaptation to altered support surface configurations. J Neurophys 1986; 55: 1369-1381.

9. Horak FB. Clinical measurement of postural control in adults. Phys Ther 1987; 67: 1881-84.

10. Forssberg H, Nashner LM. Ontogenic development of postural control in man: adaptation to altered support and visual conditions during stance. J Neurosci 1982; 2: 545-552.

11. Shumway-Cook A, Horak FB: Assessing the influence of sensory Interaction on balance: suggestion from the field. Phys Ther 1986; 66: 1548-1550.

12. Crowe TK, Deitz JC, Richardson PK, Atwater SW. Interrater reliability of the Pediatric clinical test of Sensory Interaction for Balance. Phys and Occ Ther Ped 1990; 10: 1-27.

13. Horak FB, Macpherson JM. Postural orientation and equilibrium. In: L. Rowell, J Shepherd (eds). Handbook of physiology. Section 12: Exercise: regulation and integration of multiple sensory systems. Oxford University Press, New-York, p. 255-292.

14. Di Fabio RP, Foudriat BA. Responsiveness and reliability of a pediatric strategy score for balance. Physiother Res Int 1996; 1: 180-94.

15. Rine RM, Rubish K, Feeney C. Measurement of sensory system effectiveness and maturational changes in postural control in young children. Pediatr Phys Ther 1998; 10: 16-22.

16. Hirabayashi S, Iwasaki Y. Developmental perpective of sensory organization on postural control. Brain Development 1995; 17: 111-3.

17. Shumway-Cook A, Horak FB, Black O. A critical examination of vestibular function in motor impaired learning disabled children. Int J Pediatr Otorhinolaryngol. 1987; 14: 21-30.

18. Horak FB, Shumway-Cook A, Black O. Are vestibular deficits responsible fro developmental disorders in children? Insights in Otorhinolaryngology. 1988; 3: 1-5.

19. Casselbrant ML, Furman JM, Mandel EM et al. Past history of otitis media and balance in four-year-old children. The Laryngoscope 2000; 110: 773-8.

20. Nashner LM, Shumway-Cook A, Marin O. Stance posture control in selected groups of children with cerebral palsy: deficits in sensory organization and muscular coordination. Exp Brain Res 1983; 197: 393-409.

21. Chenrg RJ, Su FC, Chen JJ, Kuan TS. Performance of static standing balance in children with spastic diplegic cerebral palsy under altered sensory environments. Am J Phys Med Rehab 1999; 78: 336-343.

22. Shumway-Cook A, Woollacott M. Dynamics of postural control in the child with Down Syndrome. Phys Ther 1985; 65: 1315-21.

23.Forslund M. Growth and motor performance in preterm children at 8 years of age. Acta Pediatr 1992; 81: 840-42.

24. Westcott, S.L., Crowe, T.K., Deitz, J.C., Richardson, P.: Test-retest reliability of the pediatric clinical test of sensory interaction for balance. Phys and Occ Ther Ped 14: 1-22, 1994.

25. Deitz JC, Richardson P, Crowe TK, Westcott SL. Performance of children with learning disabilities and motor delays on the Pediatric Clinical Test of Sensory Interaction for Balance. Phys and Occ Ther Ped 1996; 16: 1-21.

26. Richardson, P.K., Atwater, S.W., Crowe, T.K., Deitz, J.C.: Performance of preschoolers on the pediatric Clinical test of Sensory Interaction for Balance. Am J Occ Ther 46: 793-800, 1992.

27. Deitz JC, Richardson PK, Atwater SW, Crowe, TK. Performance of normal children on the pediatric clinical test of sensory interaction for balance. Occ Ther J Res 1991; 11: 336-356.

28. Gagnon I, Forget R, Swaine B, Friedman D. Balance findings after a mild head injury in children. Neurorehabilitation and Neural Repair. 2002; 16: 22-23.

Table 1: Sensory conditions used in the Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB) and in the Sensory Organization Test (SOT)

Conditions	Primary sensory system targeted	PCTSIB testing procedure	SOT testing procedure
1. Eyes open	All available systems	Eyes open while standing on floor	Eyes open while standing on fixed platform
2. Eyes closed	Proprioceptive + vestibular	Eyes closed while standing on floor	Eyes closed while standing on fixed platform
3. Vision altered	Proprioceptive + vestibular with visual conflict	Wearing dome with eyes open while standing on floor	Visual enclosure moving in phase with body sway while standing on fixed platform
4. Eyes open Perturbed support	Vision + vestibular	Eyes open while standing on foam surface	Eyes open while standing on support surface moving in phase with body swa
5. Eyes closed Perturbed support	Vestibular	Eyes closed while standing on foam surface	Eyes closed while standing on support surface moving in phase with body swa
6. Vision altered Perturbed support	Vestibular with visual conflict	Wearing dome with eyes open while standing on foam surface	Visual enclosure and support surface moving in phase with body sway

PCTSIB: Pediatric Clinical Test of Sensory Interaction for Balance; SOT: Sensory Organization Test of the Smart Balance Master™

Table 2: Performances of the children on the Pediatric Clinical Test of Sensory Interaction for Balance and in the Sensory Organization Test

	PCTSIB								SOT	
	Tandem stance				Single leg stance				Bilateral Stance	
	Holding time (s)		Summary score (0-5)		Holding time (s)		Summary score (0-5)		Stability scores (%)	
Condition	Mean	SD	Median	Range	Mean	SD	Median	Range	Mean	SD
1. Eyes open	29.4	2.4	5	3-5	26.5	7.6	5	2-5	90.0	7.9
2. Eyes closed	23.0	9.3	4	2-5	9.4	6.9	2	1-5	89.5	4.5
3. Vision altered	18.6	11.0	3	2-5	7.4	6.9	2	1-3	83.9	13.3
4. Eyes open Perturbed support	28.6	4.5	5	3-5	23.5	8.9	4	2-5	71.2	12.9
5. Eyes closed Perturbed support	14.9	11.3	2	1-5	6.0	4.4	2	1-3	50.5	20.9
6. Vision altered Perturbed support	9.6	9.3	2	1-5	3.9	2.5	2	1-2	43.8	29.1

PCTSIB: Pediatric Clinical Test of Sensory Interaction for Balance; SOT: Sensory Organization Test of the Smart Balance Master™

Table 3: Spearman rank correlation coefficients between the Pediatric Clinical Test of Sensory Interaction for Balance-holding time and the Sensory Organization Test stability score

Condition	PCTSIB-tandem/SOT		PCTSIB-SLS/SOT	
	Rho	p-value	*Rho*	p-value
1. Eyes open	0.08	0.75	0.37	0.15
2. Eyes closed	0.50	**0.05**	0.53	**0.03**
3. Vision altered	0.43	0.09	0.58	**0.02**
4. Eyes open Perturbed support	-0.17	0.52	0.18	0.51
5. Eyes closed Perturbed support	0.27	0.32	0.36	0.18
6. Vision altered Perturbed support	0.35	0.19	0.25	0.36

PCTSIB: Pediatric Clinical Test of Sensory Interaction for Balance; SOT: Sensory Organization Test of the Smart Balance Master™; SLS: single leg stance

Table 4: Spearman rank correlation coefficients between the Pediatric Clinical Test of Sensory Interaction for Balance-summary score categories and the Sensory Organization Test stability score

Condition	**PCTSIB-tandem/SOT**		**PCTSIB-SLS/SOT**	
	Rho	p-value	*Rho*	p-value
1. Eyes open	0.06	0.82	0.41	0.13
2. Eyes closed	0.46	0.09	0.45	0.09
3. Vision altered	0.49	0.06	0.59	**0.02**
4. Eyes open Perturbed support	0.28	0.33	0.20	0.47
5. Eyes closed Perturbed support	0.30	0.28	0.45	0.09
6. Vision altered Perturbed support	0.51	**0.05**	0.03	0.91

PCTSIB: Pediatric Clinical Test of Sensory Interaction for Balance; SOT: Sensory Organization Test of the Smart Balance Master™; SLS: single leg stance

Table 5: Spearman rank correlation coefficients between children's age and performance for the Pediatric Clinical Test of Sensory Interaction for Balance and for the Sensory Organization Test

	PCTSIB								**SOT**	
	Tandem stance				Single leg stance				Bilateral Stance	
	Holding time		Summary score		Holding time		Summary score		Stability score	
Condition	*Rho*	p-value	*Rho*	p-value	*Rho*	p-value	*Rho*	p-value	*Rho*	p-value
1. Eyes open	0.11	0.68	0.09	0.74	0.245	0.36	0.32	0.24	0.72	**0.002**
2. Eyes closed	0.11	0.69	0.09	0.77	0.516	**0.04**	0.37	0.18	0.73	**0.001**
3. Vision altered	0.22	0.41	0.25	0.37	0.55	**0.03**	0.50	0.06	0.81	**0.001**
4. Eyes open Perturbed support	0.38	0.14	0.56	**0.04**	0.553	**0.03**	0.59	**0.02**	0.56	**0.02**
5. Eyes closed Perturbed support	0.20	0.46	0.19	0.50	0.573	**0.02**	0.57	**0.03**	0.56	**0.02**
6. Vision altered Perturbed support	0.54	**0.03**	0.60	**0.02**	0.29	0.28	0.06	0.82	0.65	**0.006**

PCTSIB: Pediatric Clinical Test of Sensory Interaction for Balance; SOT: Sensory Organization Test of the Smart Balance Master™

CHAPITRE 5

DISCUSSION GÉNÉRALE DES RÉSULTATS

Considérant l'ensemble de nos résultats, dont la plupart ont fait l'objet de discussion au sein des articles scientifiques présentés, nous désirons reprendre ici quelques points importants à souligner dans le cadre de cette discussion générale. Ces points s'articuleront autour des grandes lignes conceptuelles du modèle du processus de production du handicap décrit dans la section introduction de cet ouvrage et repris à la figure 5.

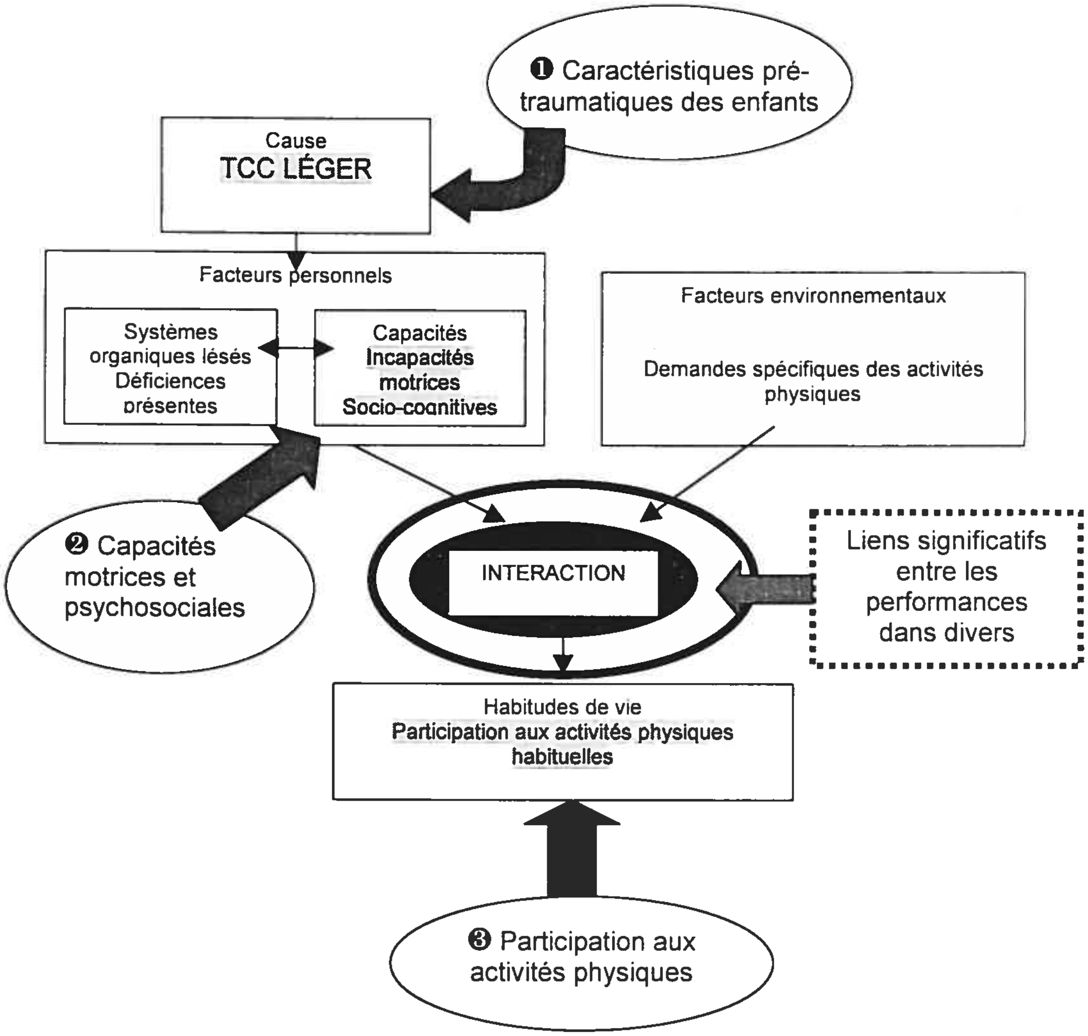


FIGURE 5: Cadre conceptuel du Processus de Production du Handicap adapté pour la discussion générale. Les constats généraux dégagés des résultats à divers niveaux sont identifiés à l'aide des flèches pleines et les liens entre les performances des entants aux différents domaines se situent au niveau de la case de l'interaction.

Il s'agit donc de revenir sur les contributions originales de nos travaux aux connaissances relatives au traumatisme crânio-cérébral léger chez l'enfant. Celles-ci seront organisées autour de trois grandes thématiques. D'abord des constats généraux seront dégagés de nos résultats à trois niveaux du modèle PPH soit concernant: ❶ les caractéristiques pré-traumatiques des sujets de l'étude, ❷ les capacités motrices et psychosociales des enfants suite au TCL et ❸ la pratique des activités physiques des enfants suite au TCL. Ensuite, suivra une discussion des liens significatifs entre les performances des enfants dans les divers domaines étudiés (représentés dans le modèle PPH par la bulle d'interaction). Finalement, les impacts de nos résultats sur la vie des enfants et leurs implications cliniques seront abordés et les perspectives futures découlant de ceux-ci seront présentées.

5.1 Constats généraux tirés des résultats

5.1.1 Constats généraux concernant les caractéristiques pré-traumatiques des sujets

Un des premiers constats pouvant être tiré de ces travaux se situe au niveau de la disponibilité de certaines données pré-traumatiques obtenues soit dans le cadre de l'histoire de cas unique décrite à l'article 1 ou soit grâce au devis et à la méthodologie utilisée pour l'étude principale. La documentation de telles caractéristiques pré-traumatiques demeure un souci constant dans les études entreprises auprès des individus après un TCL. Cependant, il est habituellement difficile d'obtenir des indices réels de l'état pré-traumatique de ces individus sauf dans le cas d'études épidémiologiques de cohortes d'individus au sein desquelles un sous-groupe de sujets subissent un TCL ou encore dans le cas de groupes d'athlètes évalués en période de pré-saison et pouvant être comparés à eux-mêmes dans l'éventualité où ils subiraient un TCL. Or, l'enfant faisant l'objet de l'histoire de cas rapportée dans le premier article fait partie de la population d'enfants pour qui des données pré-traumatiques sont habituellement si difficiles à obtenir. Les circonstances ayant permis une collecte de données pré-traumatiques pour les capacités d'équilibre de cette enfant, il est possible de dégager des constats concernant l'évolution de ses capacités avant et après le TCL. Il est utile de constater que la performance du sujet aux tests d'équilibre (BOTMP, PCTSIB et PST) mesurée cinq jours avant le traumatisme était comparable et même supérieure aux normes disponibles pour le BOTMP. Ce résultat réfute ainsi la croyance issue des premières études entreprises auprès des individus après un TCL à l'effet que certains déficits attribués au TCL aient été présents antérieurement à celui-ci (Bijur et coll., 1988). La possibilité d'identifier ici la présence et l'évolution d'incapacités d'équilibre post-trauma représente la richesse de cette contribution aux connaissances, bien qu'il ne s'agisse que du cas particulier d'une enfant.

Par ailleurs, le devis (étude prospective) et la méthodologie de l'étude principale permettait aussi d'obtenir des informations pré-traumatiques quant aux variables concernant la pratique des activités physiques. Par exemple, l'administration du Physical Activity Questionnaire au premier jour suivant le traumatisme permettait d'établir le niveau de pratique des activités physiques des enfants TCL au cours de la semaine précédant le trauma. Ceci permettait aussi la comparaison de ces caractéristiques avec celles des enfants contrôles non blessés. Il est d'intérêt de noter que les capacités psychosociales reliées à la pratique des activités physiques (perception de la compétence athlétique et efficacité personnelle) étaient comparables à celles des enfants du groupe contrôle en période pré-traumatique. Ceci peut appuyer l'idée que les incapacités d'efficacité personnelle identifiées post-TCL puissent être attribuées au TCL plutôt qu'à des particularités pré-traumatiques de ces enfants.

5.1.2 Constats généraux concernant les symptômes et capacités suite au TCL

Comme les résultats traitant des incapacités étaient organisés en deux grandes catégories, soit celles du domaine moteur et celles du domaine psychosocial, nous respecterons cette organisation pour la section suivante. Il sera cependant pertinent de débuter en discutant plus particulièrement des symptômes post-commotionnels (SPC) étudiés et rapportés dans chacun des articles en relation avec l'incapacité spécifique d'intérêt.

5.1.2.1 Symptômes post-commotionnels

La faisabilité d'utiliser une échelle standardisée et validée, avec une population pédiatrique, bien qu'elle ait été développée pour les adultes, représente le premier apport de ces travaux au niveau des SPC. En effet, contrairement aux listes habituelles recensant la présence des symptômes, le Rivermead Post Concussion Symptoms Questionnaire permet la documentation de la présence et de la sévérité des symptômes post-commotionnels et ce, en relation avec leur présence pré-traumatique. Obtenir un indice de la sévérité des symptômes plutôt que de documenter leur simple présence ou absence peut potentiellement guider les intervenants vers les enfants aux prises avec de réels problèmes. En effet, des maux de tête ou de la fatigue représentant un problème "sévère" pour l'enfant (tel que coté dans l'échelle) mériteront certainement une attention plus particulière ou des services plus spécifiques qu'un problème "léger" ayant moins d'impact sur le fonctionnement de l'enfant.

Près de 58% des enfants TCL se plaignaient d'une plus grande fatigue qu'en période pré-traumatique et 42% se plaignaient de maux de tête lors de l'évaluation 1 semaine post-trauma. Ces pourcentages baissaient à 16% et 13% respectivement lors de l'évaluation de 12 semaines. Il est intéressant de noter que ces résultats sont similaires à ceux retrouvés chez la population adulte post-TCL. Les enfants du groupe contrôle, quant à eux ne rapportaient que des niveaux négligeables de symptômes à toutes les évaluations.

5.1.2.2 Capacités motrices

S'agissant des capacités motrices étudiées dans le cadre de ces travaux, soit l'équilibre et le temps de réponse, permettons nous trois constats principaux. Premièrement, il est intéressant de noter que concernant spécifiquement les incapacités d'équilibre, les résultats obtenus auprès du cas unique (article 1), sont similaires à ceux retrouvés pour l'échantillon d'enfants de l'étude principale évalué et suivi dans le temps.

Deuxièmement, et représentant un constat de plus grande importance, les tâches dans lesquelles les incapacités d'équilibre et de temps de réponse sont identifiées méritent quelques commentaires. Les tâches dans lesquelles les enfants TCL démontrent une performance moindre que les contrôles sont généralement les plus complexes et celles où les composantes de chacune sont testées en combinaison. Par exemple, les items du BOTMP identifiés comme problématiques en temps que tâche d'équilibre étaient ceux où l'enfant devait maintenir la station debout sur une surface de support restreinte (i.e. étroite) en combinaison soit avec l'absence de repères visuels (i.e. yeux fermés), soit lorsque l'enfant devait aussi exécuter des tâches requérant un haut niveau de coordination. Le constat est le même pour les situations où les temps de réponse se sont montrés augmentés pour le groupe d'enfants TCL. Encore une fois, les incapacités sont identifiées en situations complexes non seulement du point de vue du traitement de l'information ou de la réponse motrice mais lorsque ces composantes sont présentes en combinaison l'une avec l'autre. Il n'est donc pas surprenant que ces déficits passent inaperçus lors d'évaluations simples ne s'attardant qu'à un aspect à la fois ou lors de l'évaluation neurologique de dépistage que subissent ces enfants au moment de leur congé de l'hôpital.

Troisièmement, un dernier point concerne la qualité du stimulus visuel utilisé dans la tâche de vitesse de réponse du BOTMP qui, à première vue, pouvait paraître comme une épreuve de temps de réponse simple et ne pas corroborer le constat du paragraphe précédent. Cependant, tel que discuté dans le troisième article, ce stimulus était caractérisé par le mouvement plutôt que par la luminance, ce qui représente un niveau de complexité accru requérant un niveau supérieur de traitement de l'information. Cette manière de tester les temps de réponse visuo-motrices, soit à l'aide de stimuli visuels dynamiques représente potentiellement une avenue novatrice dans l'évaluation des individus post-TCL pouvant contribuer à clarifier la nature des incapacités de temps de réponse identifiées.

5.1.2.3 Capacités psychosociales

Le caractère novateur de nos travaux dans le domaine du TCL réside ici dans deux points principaux. Le premier concerne l'étude des concepts d'efficacité personnelle dans les activités physiques et de perception de compétence athlétique chez les enfants post-TCL. Il s'agit de la première étude s'intéressant à ces questions et cherchant à examiner le retour aux activités physiques en termes autres que la détermination du moment où celui-ci serait sécuritaire. Le développement préliminaire d'un outil s'intéressant à l'efficacité personnelle dans les activités physiques post-TCL constitue un apport significatif pour la poursuite des travaux dans ce domaine. Bien décrit dans le quatrième article de cette thèse, l'outil s'avère prometteur de par sa stabilité pendant la période de 12 semaines auprès du groupe contrôle chez qui des variations importantes de l'efficacité personnelle n'étaient pas attendues, et de par sa capacité à identifier les différences entre les groupes 12 semaines après le TCL.

Le deuxième point réside dans le fait que l'incapacité psychosociale identifiée concerne l'efficacité personnelle pour la pratique des activités physiques et non la perception de la compétence athlétique. Comme les assises de ces travaux se trouvaient dans les commentaires d'enfants ayant subi un TCL à l'effet qu'ils ne se sentaient pas comme avant le traumatisme dans la pratique de leurs activités physiques, il est particulièrement novateur d'avoir pu traduire ces sentiments en incapacités mesurables. Il ne s'agit bien entendu que d'un suivi de courte durée (i.e. 12 semaines), et les informations au sujet de ce qui se passe après cette période ne sont pas disponibles. Cependant, comme les enfants se révèlent très actifs dans la pratique de leurs activités physiques, tel que mesuré par le Physical Acticity Questionnaire à l'évaluation de 12 semaines, la pertinence de se soucier d'une diminution de l'efficacité personnelle à ce moment demeure pertinente. Pour conclure, l'efficacité personnelle est un concept complexe et, en accord avec les constats sur la nature des incapacités motrices présentés à la section précédente, cet aspect de complexité caractérise peut-être l'ensemble des déficits identifiés suite à un TCL chez l'enfant.

5.1.3 Constats généraux concernant la participation aux activités physiques

Il apparaît essentiel de revenir sur le fait que le niveau de participation aux activités physiques est maintenu 12 semaines post-TCL, lorsque comparé à la période immédiatement pré-traumatique. Il faut donc se rendre à l'évidence que les incapacités identifiées dans les domaines de l'équilibre, des temps de réaction et de l'efficacité personnelle n'affectent pas *le choix* ou *la décision* de participer aux activités physiques habituelles et donc que le TCL chez les enfants de notre échantillon n'affectent pas leur niveau de participation. Il s'agit maintenant de se demander si d'autres aspects reliés à la pratique des activités physiques, comme la performance, méritent d'être examinés suite à un TCL.

5.2 Relations d'intérêts entre les performances des enfants dans les domaines étudiés

L'évaluation de plusieurs domaines au sein d'une même étude avec des enfants ayant eu un TCL permettait, pour la première fois, d'explorer les relations potentielles entre ces divers domaines. Certains de ces liens ont déjà été discutés au sein des articles inclus dans cette thèse et nous les rappellerons brièvement dans la première partie de cette section. Dans un deuxième temps, de nouveaux liens d'intérêts seront présentés pour la première fois.

5.2.1 Relations déjà établies au sein des articles

En explorant les relations entre les capacités et certaines caractéristiques du TCL, nous désirions non seulement explorer les pistes d'interprétation des résultats mais aussi établir la possibilité de pouvoir identifier un sous-groupe d'enfants particulièrement susceptibles de développer des problèmes. Il convient donc de résumer brièvement les liens déjà identifiés et présentés au sein des articles scientifiques de la section résultats.

Ainsi, pour ce qui est de l'équilibre (article 2), la performance aux épreuves du BOTMP à l'évaluation 1 semaine post-trauma était corrélée avec la sévérité du TCL (i.e. grade de commotion) subi par les enfants et avec les SPC mesurés lors de la même évaluation. La performance aux épreuves de temps de réponse (article 3) ne présentait quant à elle aucune relation avec les caractéristiques du TCL ou avec les SPC. Pour les variables d'activités physiques (article 4), le niveau d'efficacité personnelle 12 semaines après le TCL était négativement corrélé avec les SPC présents à 4 et 12 semaines post-trauma. Ainsi, nous ne pouvons pas conclure que des caractéristiques particulières arrivent à prédire des incapacités dans tous les domaines. Cependant, les incapacités d'équilibre sont liées à la sévérité du TCL et les SPC semblent liés aux incapacités d'équilibre et d'efficacité personnelle.

5.2.2 Relations supplémentaires d'intérêt

En plus des liens déjà présentés dans les articles, trois relations supplémentaires et intéressantes furent observées lorsque les domaines de capacité étaient mis en interrelations. Ces analyses, non présentées dans les articles, seront discutées ici.

Premièrement, les performances des enfants ayant subi un TCL aux épreuves d'équilibre du BOTMP sont corrélées à celles de l'épreuve de temps de réponse du même test pour les évaluations de la première et de la quatrième semaine (Spearman r=0.374-0.538). Cette relation peut être interprétée comme illustrant un effet général du TCL sur la performance motrice telle qu'évaluée par le BOTMP. Il peut être intéressant cependant, d'explorer une autre interprétation de cette relation entre les performances à l'équilibre et au temps de réponse du BOTMP.

En effet, l'examen des relations existant entre les performances d'équilibre au BOTMP et celles au temps de réponse obtenues avec le "tapis" d'interrupteurs pour l'évaluation des temps de réponse peuvent ainsi fournir des pistes intéressantes pour l'interprétation de relations potentielles entre l'équilibre (mesuré avec le test BOTMP) et le temps de réponse en général. D'abord, bien qu'une relation existe entre les performances à l'équilibre du BOTMP et celles à l'épreuve du temps de réponse du BOTMP, qui est une épreuve de temps de réaction simple pour le membre supérieur, il n'existe pas de telles relations significatives entre les performance aux épreuves de l'équilibre du BOTMP et celles des temps de réponse simples au membre supérieur du "tapis". Ceci supporterait que la performance à l'épreuve de vitesse de réponse du BOTMP n'est pas simplement une tâche de temps de réaction simple. Par ailleurs, des relations entre les performances à l'équilibre du BOTMP et celles aux épreuves de temps de réponse du "tapis" ne deviennent évidentes que lorsque l'épreuve de temps de réponse est au choix (r=0.376) ou au choix inversé (r=0.418) pour le membre supérieur. La notion de complexité de la tâche de temps de réponse soit en termes de stimuli (i.e. stimulus de mouvement dans le BOTMP) ou de réponse (i.e. au choix ou inversé dans le "tapis") serait donc nécessaire à l'émergence de relations entre l'équilibre et les temps de réponse dans le cas des membres supérieurs. Au contraire, dans le cas des épreuves du "tapis" pour les membres inférieurs, les TR de celles-ci sont tous corrélés avec les performances d'équilibre du BOTMP. Les réponses motrices des épreuves aux membres inférieurs sont naturellement plus complexes que celles des membres supérieurs à cause, entre autres, des ajustements posturaux et du niveau de coordination entre les segments corporels. Ceci supporte, encore une fois, la notion de complexité nécessaire aux tâches pour qu'elles arrivent à identifier les troubles présents suite à un TCL.

Le deuxième lien d'intérêt se retrouve au niveau d'une faible corrélation existant entre la performance des enfants post-TCL au sous-test d'équilibre du BOTMP à 12 semaines et leur niveau de participation aux activités physiques (performance au Physical Activity Questionnaire (PAQ)) au même moment (r=0,392; p=0,02). Cette corrélation pourrait illustrer l'influence de facteurs moteurs sur la décision de participer aux activités physiques et ce, pour tous les enfants, blessés ou non. Cependant, ce n'est pas le cas car parmi les enfants contrôles de notre échantillon nous ne pouvons retrouver ce lien. Nous suggérons donc qu'un effet TCL est nécessaire pour faire apparaître cette relation et que parmi les enfants ayant subi un TCL, ceux qui auront retrouvé un équilibre suffisant auront plus de chance d'avoir choisi de reprendre un niveau élevé de participation aux activités physiques tel que mesuré par le PAQ 12 semaines.

Finalement, le dernier lien que nous désirons exposer ici présente un intérêt non négligeable. Il s'agit d'une relation existant entre le niveau d'efficacité personnelle des enfants post-TCL à la dimension "mTBI related problems" du questionnaire lors de l'évaluation de 12 semaines et leur performance au Postural Stress Test (PST), une des épreuves d'équilibre, à 4 semaines post-trauma (r=0.386). Les incapacités d'équilibre identifiées 4 semaines post-TCL revêtent une importance particulière car il s'agit du moment où les enfants ont la permission de reprendre leurs activités physiques et commencent ainsi à construire leur jugement d'efficacité personnelle. L'épreuve d'équilibre du PST est celle impliquant l'évaluation de l'intégrité des réactions aux perturbations externes. Des perturbations externes risquent d'être très présentes dans la pratique des activités physiques. Des difficultés à réagir correctement lorsqu'elles surviennent contribuent à altérer les performances initiales des enfants pendant ces activités. Ces performances sont utilisées dans la construction d'un jugement d'efficacité personnelle ultérieure et contribuent certainement à la diminution de celle-ci observée 12 semaines post-TCL.

5.3 Impacts des résultats sur la vie des enfants et implications cliniques

La troisième et dernière partie de cette discussion sera dédiée aux impacts des résultats des travaux expérimentaux sur la vie des enfants dans le contexte de la pratique des activités physiques post-TCL et sur leurs implications pour la clinique. Certaines de ces implications ont été soulevées dans les sections précédentes mais nous nous permettrons ici d'élargir cette discussion.

D'abord, concernant les capacités motrices, la présence de problèmes d'équilibre et de temps de réponse persistant pour certains enfants jusqu'à au moins 12 semaines post-trauma soulève des questions du point du vue de la sécurité dans la pratique des activités physiques. Les enfants retournent à la pratique de ces activités dès la 4^e semaine post-trauma. Cependant, il est démontré que les enfants post-TCL sont plus à risque de subir un second TCC au cours de la première année suivant celui-ci que des enfants ayant subi des blessures orthopédiques. Ces problèmes d'équilibre et de temps de réponse pourraient-ils être la cause ou être reliés à ce risque plus élevé? Le suivi des enfants à plus long terme permettrait d'évaluer s'il y a corrélation entre ces incapacités et la présence d'un second TCC. Pour l'instant, un retour plus sécuritaire aux activités physiques pourrait être assuré si les enfants et leurs parents étaient au moins avisés des risques potentiels associés à la pratique d'activités incluant des composantes d'équilibre et de temps de réponse.

Ensuite, nous ne pouvons nous satisfaire que les enfants soient retournés à un niveau pré-traumatique de participation aux activités physiques 12 semaines post-TCL sans se préoccuper d'autres aspects liés à la participation tels le niveau de performance ou la satisfaction des enfants pendant leur participation. Il s'agit de savoir si ces aspects sont influencés par un TCL particulièrement parce que ceci semble préoccuper les enfants eux-mêmes. Bien entendu nous n'avons pas de données à ce sujet, mais le lien postulé par Bandura entre les niveaux d'efficacité personnelle dans les activités physiques et la performance ultérieure à ces activités soulève cette question. Il est difficile d'obtenir des mesures objectives évaluant la performance dans un cadre non structuré de participation aux activités physiques tel celui de notre population cible. La problématique étant que seul l'enfant peut comparer la qualité de sa performance avant et après le traumatisme. Cependant des études pilotes de nature qualitative auprès de groupes restreints d'enfants pourraient être entreprises afin d'arriver à élucider si des aspects autres que la participation reliés à la pratique des activités physiques sont affectés suite au TCL. D'autre part et possiblement en parallèle, il nous apparaît que la question de comparaison de la performance avant et après le traumatisme doit être faite par une tierce partie (e.g. instructeur, entraîneur, parent) dans le cadre d'une activité physique structurée, telle un sport requérant une participation active et soutenue incluant des compétitions.

Finalement, l'identification dans le cadre des travaux expérimentaux de nouvelles incapacités suite à un TCL soulève trois questions importantes du point de vue clinique: 1) devrait-on inclure des évaluations de ces capacités dans la pratique clinique auprès de ces enfants? 2) quels outils semblent les plus aptes à identifier les incapacités significatives sans alourdir le processus d'évaluation? et 3) doit-on intervenir auprès de ces enfants afin de minimiser l'impact de ces incapacités et permettre un retour plus harmonieux aux activités physiques de la vie quotidienne suite à un TCL?. Il est entendu que la poursuite des travaux permettra une réponse plus complète à ces questions mais certaines recommandations peuvent être faites dès maintenant. Nous croyons que l'introduction d'évaluations de routine de certains aspects touchant l'équilibre, les temps de réponse et l'efficacité personnelle serait justifiée particulièrement au moment du retour aux activités physiques (2 à 4 semaines post-TCL) afin d'identifier les enfants devant être soumis à une surveillance plus particulière suite au TCL. Concernant l'équilibre et les temps de réponse, des tâches complexes telles celles des sous-tests d'équilibre et de vitesse de réponse du BOTMP sembleraient avoir une sensibilité suffisante pour pouvoir fournir des indices certains quant à la présence de difficultés dans ces domaines. Pour ce qui est de l'efficacité personnelle, le questionnaire développé dans le cadre de ces travaux étant le seul disponible, nous suggérons la poursuite des travaux de validation de l'outil, mais en parallèle, son utilisation de routine tant pour établir le niveau pré-traumatique de l'efficacité personnelle que pour documenter son évolution post-trauma.

Enfin, la question de l'intervention à préconiser pour traiter des incapacités nouvellement identifiées chez cette clientèle ne peut être passée sous silence. Dans un premier temps, la nature spécifique et probablement transitoire des incapacités à la fois motrices et psychosociales relevées dans le cadre de nos études, ainsi que leur amélioration dans le temps, sembleraient commander une approche d'intervention visant à reconnaître l'existence des problèmes et à rassurer les enfants quant à leur résolution dans les prochaines semaines. Les études d'interventions au niveau des SPC utilisant une telle approche démontrent son efficacité (King et coll., 1997; Wade et coll., 1998). Comme la pratique actuelle au sein du programme de neurotraumatologie de l'Hôpital de Montréal pour Enfants auprès de ces enfants implique déjà un contact téléphonique quatre semaines post-TCL ayant pour but de s'assurer d'une évolution générale favorable, il serait faisable d'ajouter ce type d'intervention pour les enfants présentant des difficultés d'ordre plus spécifique dans les domaines étudiés. Enfin, l'attitude des intervenants lorsqu'impliqués auprès des enfants revêt aussi une importance certaine. En effet, minimiser l'importance des effets du TCL ne peut que contribuer au sentiment d'incompréhension des enfants lorsque les choses ne rentrent pas dans l'ordre immédiatement. Si une démarche de réassurance s'avérait infructueuse, des interventions spécifiques au niveau moteur, ou psychologiques seraient à explorer sans toutefois leur accorder une importance démesurée.

5.4 Perspectives et avenues de recherche à poursuivre

La poursuite des travaux entrepris dans le cadre de cette thèse s'effectuera en suivant deux axes principaux soient 1) la poursuite de l'étude des facteurs du Processus de Production du Handicap non abordés dans le contexte de la pratique des activités physiques soit les facteurs environnementaux incluant la famille, l'entourage des enfants et les services reçus suite au TCL (i.e. séance d'information au congé et contact téléphonique quatre semaines post-TCL) et 2) la poursuite du développement de l'outil d'efficacité personnelle utilisée dans notre étude.

Premièrement, en se rapportant au PPH ayant servi de cadre conceptuel pour ces travaux, l'absence de mesures s'adressant aux facteurs environnementaux en cause présente une avenue incontournable pour la poursuite de la démarche de recherche. Nous pouvons situer ceux-ci à plusieurs niveaux mais il semblerait important de s'attarder dans un premier temps aux facteurs reliés à la famille et à l'environnement social immédiat de l'enfant. En effet, une relation proche et satisfaisante de l'enfant avec sa cellule familiale de même que la disponibilité d'un réseau de support extra-familial sont deux des trois facteurs (le troisième étant les facteurs de protection de l'enfant) constituant une triade protectrice associée à la résilience d'un enfant en situation de stress ou de crise (Cowen et coll., 1991). L'exploration de l'anxiété parentale, de la présence de support parental, de la présence de support extra-familial, et de la qualité des relations parents-enfants, professeurs-enfants, pourraient ajouter à la compréhension des facteurs pouvant influencer la récupération suite au TCL. Dans un deuxième temps, l'examen des politiques plus globales de prise en charge des TCL et la présence d'une attitude de minimisation des problèmes au niveau des organismes finançant les programmes de prise en charge des individus (e.g. SAAQ, CSST) peut aussi influencer les choix organisationnels de suivi de ces enfants et méritent une certaine attention.

La poursuite du processus de validation du questionnaire d'efficacité personnelle face à la pratique des activités physiques représente un deuxième axe de recherche émanant de nos travaux. Cet outil fut développé selon une procédure reconnue et il s'avère prometteur dans l'identification d'incapacités d'efficacité personnelle. Cependant, ses qualités psychométriques demeurent à établir formellement. Ceci devrait être entrepris dans le cadre d'un suivi systématique des enfants admis suite à un TCL et les résultats serviront à compléter la démarche de développement de cet outil.

5.5 Limites de nos travaux

Les limites inhérentes à tout projet de recherche clinique sont inévitablement retrouvées ici et nos résultats doivent être considérés dans le contexte de ces limites. D'abord, certains outils développés pour les adultes n'avaient jamais été utilisés avec une population d'enfants. Bien que nous ayons montré la faisabilité de leur utilisation avec cette clientèle et que la sensibilité à identifier certains déficits semble valider leur utilisation, il n'en demeure pas moins que l'absence de normes et de qualités psychométriques particulières aux enfants ou au TCL représente une limite quant à l'interprétation de nos résultats. Ensuite, le recrutement des enfants se limitait exclusivement à une population hospitalière avec les biais potentiels y étant associés (e.g. région géographique spécifique, symptômes plus sévères). Comme il est reconnu que jusqu'à 25% de tous les TCL ne sont jamais rapportés, notre méthode de recrutement contribue certainement à limiter la généralisation des résultats à tous les cas d'enfants ayant subi un TCL. La taille de l'échantillon pourrait aussi être soulevée comme limite à la généralisation des résultats. Cependant, le calcul du nombre nécessaire de sujets pour s'assurer d'une puissance raisonnable dans la détection de différences entre les groupes ayant été fait a priori, nous pouvons assumer que les différences identifiées entre les groupes sont réelles, au moins pour l'outil principal de mesure soit le BOTMP. Concluons en soulignant que la durée restreinte de la période de suivi des enfants représente une dernière limite. En effet, la présence persistante de certaines incapacités à la fin de la période de 12 semaines nous force à nous questionner sur l'évolution ultérieure de celles-ci. Un suivi d'une durée minimale de 6 à 12 mois serait fortement recommandé dans le cadre d'études futures traitant du même type d'incapacités suite à un TCL.

CHAPITRE 6

CONCLUSION

Au terme de ce travail, de nombreuses questions demeurent quant au **devenir** des enfants suite à un traumatisme crânio-cérébral léger, mais quelques conclusions peuvent tout de même être tirées de nos résultats D'abord, les incapacités **d'équilibre** identifiées chez un nombre important d'enfants, semblant persister trois mois après le TCL et reliées à sa sévérité, doivent être considérées lors de la prise en charge de ces enfants au moins du point de vue de leur sécurité. Ensuite, les difficultés liées au **temps de réaction** semblent quant à elles de nature plus transitoire mais les indices quant à la spécificité des stimuli et réponses nécessaires à leur identification fournissent des pistes intéressantes pour la poursuite des travaux dans ce domaine et particulièrement dans le cadre d'un questionnement sur l'atteinte de fonctionnement de haut niveau au point de vue de l'intégration perceptivo-motrice. Finalement, l'identification d'une diminution du sentiment **d'efficacité personnelle** face à la pratique des activités physiques chez les enfants post-TCL, allant dans le sens des inquiétudes exprimées par les enfants de manière anecdotique, est peut-être un des éléments les plus intéressants et novateurs de ces travaux. Il impliquent que les conséquences d'un TCL pourraient aussi avoir un impact psychosocial et non seulement biomédical. Cette première étude devrait cependant encourager la poursuite de travaux au niveau de l'identification des incapacités et des facteurs environnementaux en cause, particulièrement au niveau des interventions possibles et de l'amélioration des services offerts à ces enfants. Ces orientations futures représentent certainement les avenues de recherche les plus susceptibles d'améliorer la qualité de vie des enfants suite à un TCL.

CHAPITRE 7
SOURCES DOCUMENTAIRES

Adams JH, Graham DI, Murray LS, Scott G. Diffuse axonal injury due to non missile head injury in humans: an analysis of 45 cases. Annals of Neurology 1982; 12: 557.

Alexander MP. Neuropsychiatric correlates of persistent postconcussive syndrome. Journal of Head Trauma Rehabilitation 1992; 7: 60-69.

Alexander MP. Mild traumatic brain injury: pathophysiology, natural history, and clinical management. Neurology 1995; 45: 1253-60.

Alves WM, Colohan ART, O'Learly TJ, Rimel RW, John JA. Understanding post-traumatic symptoms after minor head injury. Journal of Head Trauma Rehabilitation 1986; 1: 1-12.

Alves WM, Macciocchi SN, Barth J. Postconcussive symptoms after uncomplicated mild head injury. Journal of Head Trauma Rehabilitation 1993; 8: 48-59.

American Academy of Neurology. Report from the Quality Standards Subcommittee. Practice parameter: The management of concussion in sports (summary statement). Neurology 1997; 48: 581-585.

American Academy of Pediatrics. The management of minor closed head injury in children. Pediatrics 1999; 104: 1407-1415.

Anson JG. Memory drum theory: Alternative tests explanations for the complexity effects on simple reaction time. Journal of Motor Behavior 1982; 14: 228-246.

Asarnow RF, Satz P, Light P, Lewis R, Neumann E. Behavior problems and adaptive functioning in children with mild and severe closed head injury. Journal of Pediatric Psychology 1991; 16: 543-555.

Ashwal S, Holshouser BA, Shu SK, Simmons PL, Perkin RM, Tomasi LG, Knierim DS, Sheridan C, Craig K, Andrews GH, Hinshaw DB. Predictive value of proton magnetic resonance spectroscopy in pediatric closed head injury. Pediatric Neurology 2000; 23: 114-125.

Bandura A. *Social foundations of thought and action: a social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall, 1986, p.391.

Bandura A. Regulation of cognitive processes through perceived self-efficacy. Developmental Psychology 1989; 25: 729-735.

Bandura A. Perceived self-efficacy in the exercise of personal agency. Applied sport psychology 1990; 2: 128-63.

Bernstein DM. Recovery from mild head injury. Brain injury 1999; 13: 151-172.

Berthoz A. Rôle de la proprioception dans le contrôle de la posture et du geste. Contribuition dynamique de quelques récepteurs à la détection du mouvement. In: H Hécaen, M. Jeannerod (eds) *Du contrôle moteur à l'organisation du geste*. Masson, Paris, 1978; p.187-224.

Betz NE, Hackett G. Applications of self-efficacy theory to understanding career choice behavior. Journal of Social and Clinical Psychology 1986; 4: 279-289.

Bijur P, Golding J, Haslum M, Kurzon M. Behavioral Predictors of Injury in School age Children. American Journal of Disease in Children 1988; 142: 1307-1312.

Bijur P E, Haslum M, Golding J. Cognitive and behavioral sequelae of mild head injury in children. Pediatrics 1990; 86: 337-344.

Black FO, Wall C, Nashner LM. Effects of visual and support surface orientation referencesupon postural control in vestibular deficient subjects. Acta Otolaryngologica 1983; 95: 199-210.

Black P, Jeffries J, Blumer D. The post-traumatic syndrome in children. In Walker AE, Caveness WJ, Critchley M, eds *The late effects of head injury*. Springfield, IL: Charles C Thomas; 1969: 142-149.

Bohannon R, Larkin PA, Cook AC, Gear J, Singer J: Decrease in timed balance test scores with aging. Physical Therapy 1984; 64: 1067-1070.

Bohnen N, Jolles J. Neurobehavioral aspects of postconcussive symptoms after mild head injury, The Journal of Nervous and Mental Disease 1992; 180: 683-692.

Bohnen N, Twijnstra A, Jolles J: Persistence of post-concussional symptoms in uncomplicated mildly head injured patients: a prospective cohort study 1993, 6: 193-200.

Boll TJ, Barth J. Mild head injury. Psychiatric Development 1983; 1: 263-276.

Brooks DN, McKinlay WW. Personality and behavior change after severe blunt head injury: a relative's review. Journal of Neurology Neurosurgery and Psychiatry 1983; 46: 336-344.

Brown G, Chadwick O, Schaffer D, Rutter M, Traub M. A prospective study of children with head injuries, II. Psychiatric sequelae. Psychological Medicine 1981; 11: 49-62.

Bruininks RH. *The Bruininks-Oseretsky Test of Motor Performance*, Circle Pines, MN: American guidance service; 1978.

Burkinshaw J. Head injuries in children. Observations on their incidence and causes with an enquiry into the value of routine skull x-rays. Archives of Disease in Childhood 1960; 205-214.

Burton AW, Davis WE. Assessing balance in adapted physical education: fundamental concepts and applications. Adapted Phsyical Activity Quarterly 1992; 9: 14-46.

Butcher J, Sallis JF, McKenzie TL, Alcaraz JE. A longitudinal study of children's participation in organized sport and instructional programs. Avante 2001; 7: 86-96.

Butterbaugh G, Roochvarg L, Slater-Rusonis E, Miranda D, Heald F. Academic abilities in adolescents with traumatic brain injuries: An 18 month follow-up study. Journal of Clinical and Experimental Neuropsychology 1993; 15: 84.

Cantu RC. Guidelines for return to contact sports after a cerebral concussion. Physician in Sports Medicine 1986; 14: 75-83.

Cecchini AS. Functional assessment after traumatic brain injury. Neurology Report 1998; 22: 136-43.

Chamberlin CJ, Magill RH. Preparation and control of rapid multisegmented responses in simple and choice environments. Research Quarterly for Exercise and Sport 1989; 60: 256-267.

Chaplin D, Deitz J, Jaffe KM. Motor performance in children after traumatic brain injury. Archives of Physical Medicine and Rehabilitation 1993; 74: 161-4.

Charron, L.: *Profil des victimes d'un traumatisme crânio-cérébral à la suite d'un accident de la route au Québec, 1987*. Société de l'Assurance Automobile du Québec, 1992.

Christina RW, Fishman MG, Lambert AL, Moore JF. Simple reaction time as a function of response complexity: Christina. (1982) revised. Research quarterly for Exercise and Sport 1985; 56: 316-322.

Cicerone K.D. Clinical sensitivity of four measures of attention to mild traumatic brain injury. The Clinical Neuropsychologist 1997; 11: 266-272.

Colorado Medical Society: Reports of the sports medicine committee: Guidelines for the management of concussion in sports, revised. Denver: Colorado Medical Society, 1991.

Concussion in Sport Group (CIS). Summary and agreement statement of the 1st International symposium on concussion in sport, Vienna 2001. Clinical Journal of Sport Medicine 2002; 12: 6-11.

Cowen EL, Work WC, Hightower AD, Wyman PA, Parker GR, Lotyczewski BS. Toward the development of a measure of perceived self-efficacy in children. Journal of Clinical Child Psychology 1991; 20: 169-178.

Crocker PRE, Bailey DA, Faulkner RA, Kowalsky K, McGrath R. Measuring general levels of physical activity: preliminary evidence for the physical activity questionnaire for older children. Medicine and Science in Sports and Exercise 1997; 29: 1344-1349.

Crowe TK, Deitz JC, Richardson PK, Atwater SW. Interrater reliability of the Pediatric clinical test of Sensory Interaction for Balance. Physical and Occupational Therapy in Pediatrics 1990; 10: 1-27.

Davis RL, Hughes M, Gubler KD, Waller PL, Rivara FP. The use of cranial CT scans in the triage of pediatric patients with mild head injury. Pediatrics 1995; 95: 345-349.

Diener HC, Dichgans J. On the role of vestibular, visual and somatosensory information for dynamic postural control in humans. Progressive Brain Research 1988; 76: 253-261.

Dietrich AM, Bowman MJ, Ginn-Pease ME, Kosnik E, King DR. Pediatric head injuries: can clinical factors reliably predict an abnormality on computed tomography. Annals of Emergency Medicine 1993; 22: 1535-1540.

Dilorio C, Faherty B, Manteuffel B. The development and testing of an instrument to measure self efficacy in individuals with epilepsy. Journal of Neuroscience Nursing 1992; 24: 9-13.

Division of Injury Control. Center for environmental health and Injury Control. Centers for Disease Control. Childhood Injuries in the United States. American Journal of Disease in Children. 1990; 144: 627-46.

Dumont C. Les facteurs favorisant la participation sociale des adultes ayant subi un traumatisme crânio-cérébral. (abstract) Proceedings of the Journées scientifiques du Réseau provincial de recherche en adaptation-réadaptation, 23-24 mai 2003, p.20.

Eason BL, Surburg PR. Effects of midline crossing on reaction time and movement time with adolescents classified as mildly retarded. Adapted Physical Activity Quarterly 1993; 10: 269-280.

Evans RW. The post-concussion syndrome and the sequelae of mild head injury. Neurologic Clinics 1992; 10: 815-884.

Evans RW. Postconcussion syndrome and whiplash injuries. In Narayan RK, Wilberger JE, Povlishock JT (eds) Neurotrauma, McGraw Hill Cies Inc, 1996: 593-609.

Ewing-Cobbs L, Levin HS, Fletcher JM, Miner ME, Eisenberg HM. The Children' Orientation and Amnesia Test: relationship to severity of acute head injury and to recovery of memory. Neurosurgery 1990; 27: 683-691.

Ewing-Cobbs L, Miner ME, Fletcher JM, Harvey SL. Intellectual, Motor and language Sequelae Following Closed Head Injury in Infants and preschoolers. Journal of Pediatric Psychology 1989; 14: 531-547.

Fay GC, Jaffe KM, Polissar NL, Liao S, Martin KM, Shurtleff HA. Mild pediatric brain injury: a cohort study. Archives of Physical Medicine and Rehabilitation 1993; 74: 895-901.

Fletcher JM, Ewing-Cobbs, L, Miner, M, Levin, HS, Eisenberg, HM. Behavioral changes after closed head injury in children. Journal of Consulting and Clinical Psychology 1990; 58: 93-98.

Fletcher JM, Miner ME, Ewing-Cobbs L. Age and recovery from head injury in children: developmental issues. In: Levin HS, Eisenberg HM, Grafman J (eds) Neurobehavioral recovery from head injury. New York: Academic Press. 1987, p. 279-291.

Forssberg H, Nashner LM. Ontogenic development of postural control in man: adaptation to altered support and visual conditions during stance. Journal of Neuroscience. 1982; 2: 545-552.

Fougeyrollas P, Bergeron H, Cloutier K, Côté J, St-Michel G. Classification québecoise: Processus de production du Handicap, RIPPH, Québec 1998.

Fougeyrollas P, St-Michel G. Le processus de production du handicap. Réseau international CIDIH 1991; 4.

Gagnon I, Forget R, Friedman D, Sullivan SJ. Motor performance following a mild traumatic brain injury in children: an exploratory study. Brain Injury 1998; 12: 843-853.

Gagnon I, Friedman D, Swaine B, Forget R. Balance findings in a child before and after a mild head injury. Journal of Head Trauma Rehabilitation 2001; 16: 595-602.

Garnett MR., Blamire AM., Rajagopalan B., Styles P., Cadoux-Hudson TAD. Evidence for cellular damage in normal appearing white matter correlates with injury severity in patients following traumatic brain injury, a magnetic resonnace spectroscopy study. Brain 2000; 123: 1403-09.

Geurts ACH, Knoop JA, van Limbeek J. Is postural control associated with mental functioning in the persistent postconcussion syndrome? Archives of Physical Medicine and Rehabilitation 1999; 80: 144-9.

Geurts ACH, Ribbers GM, Knoop JA, von Limbeek J. Identification of static and dynamic postural instability following traumatic brain injury. Archives of Physical Medicine and Rehabilitation 1996; 77: 639-44.

Gould D. Sport psychology in the 1980s; status, direction and challenge in youth sport research. Journal of Sport Psychology 1982; 4: 203-218.

Graham DI. Neuropathology of head injury. In: Narayan RK, Wilberger JE, Povlishock JT, editors. *Neurotrauma*. McGraw Hill Cies inc, 1996: 43-59.

Greenwald BD, Cifu DX, Marwitz JH, Enders LJ, Brown AW, Englander JS. Factors associated with balance deficits on admission to rehabilitation after traumatic brain injury: a multicenter analysis. Journal of Head Trauma Rehabilitation 2001; 16: 238-52.

Gulbrandsen GB. Neuropsychological Sequelae of light head injuries in older children 6 months after trauma. Journal of Clinical Neuropsychology 1984; 6: 257-68.

Guskiewicz KM, Riemann BL, Perrin DH, Nashner LM. Alternative approaches to the assessment mild head injury in athletes. Medicine and Science in Sports and Exercise 1997; 29 suppl: 213-221.

Guthkelch AN. Post-traumatic amnesia, post-concussional symptoms and accident neurosis. European Neurology 1980; 19: 92-102.

Haaland KY, Temkin N, Randhal G, Dikmen S. Recovery of simple motor skills after head injury. Journal of Clinical and Experimental Neuropsychology 1994; 16: 448-456.

Harbin G, Durst L, Harbin D. Evaluation of oculomotor response in relationship to sports performance. Medicine and Science in Sports and Exercise 1989; 21: 258-262.

Harter S. The Perceived Competence Scale for Children. Child Development 1982; 53: 87-97.

Harter S. Manual for the Self-Perception Profile for Children (Revision of the Perceived Competence Scale for Children). Denver, CO: University of Denver, 1985.

Harter S. Manual for the Self-Perception Profile for Adolescents. Denver, CO: University of Denver, 1988.

Harter S, Connell JP. A model of children's achievement and related self-perceptions of competence, control and motivational orientation. Advances in Motivation and Achievement 1984; 3: 219-250.

Henry FD, Rodgers DE. Increased response latency for complicated movements and a memory drum theory of neuro-motor reaction. Research Quarterly 1960; 31: 448-458.

Hetherington CR, Stuss DT, Finlayson MA. Reaction time and variability 5 and 10 years after traumatic brain injury. Brain Injury 1996; 10: 473-486.

Hillier SL, Hiller JE, Metzer J. Epidemiology of traumatic brain injury in south Australia. Brain Injury 1997; 11: 649-659.

Hillier SL, Sharpe MH, Metzer J. Outcomes 5 years post-traumatic brain injury (with further reference to neurophysical impairment and disability). Brain Injury. 1997;11:661–675

Hofman PAM, Stapert SZ, Van Kroonenburgh MJPG, Jolles J, de Kruijk J, Wilmink JT. MR imaging, single photon emission CT, and neurocognitive performance after mild traumatic brain injury. AJNR American Journal of Neuroradiology 2001; 22: 441-49.

Horak FB. Clinical measurement of postural control in adults. Physical Therapy 1987; 67: 1881-1884.

Horak FB. Motor control models underlying neurologic rehabilitation of posture in children. Medicine and Sport Science 1992; 36: 21-30.

Horak FB, Henry SM, Shumway-Cook A. Postural perturbation, new insights for the treatment of balance disorders. Physical Therapy 1997; 77: 517-533.

Horak FB, Macpherson JM. Postural orientation and equilibrium. In: L Rowell, J Shepherd (eds) Handbook of physiology. Section 12: *Exercise: Regulation and integration of multiple systems.* Oxford university Press, New York, 1996, p. 225-292.

Horak FB, Nashner LM. Central programming of postural movements: adaptation to altered support surface configurations. Journal of Neurophysiology 1986; 55: 1369-1381.

Horak FB, Nashner LM, Diener HC. Postural strategies associated with somatosnesory and vestibular loss. Experimental Brain Research 1990; 82: 167-177.

Horak FB, Shupert CL, Dietz V, Horstmann G. vestibular and somatosensory contributions to responses to head and body displacements in stance. Exp Brain Res 1994; 100: 93-106.

Horn TS. *Advances in Sport Psychology*. Human Kinetics. Champaign,IL. 1992: 13-22.

Ichise M, Chung DG, Wang P, Wortzman G, Gray BG, Franks W. Technetium-99m-HMPAO SPECT in the evaluation of patients with chronic traumatic brain injury: a correlation with neuropsychological performance. Journal of Nuclear Medicine 1994; 35: 217-226.

Ingebrigtsen T, Romner B. Routine early CT-scan is cost saving after minor head injury. Acta Neurologica Scandinavia 1996; 93: 207-210.

Inglis JT, Horak FB, Shupert CL, Jones-Rycewicz C. The importance of somatosensory information in triggering and scaling automatic postural responses in humans. Experimental Brain Research 1994; 101: 159-164.

Jacobs A, Put E, Ingels M, Put T, Bossuyt A. One year follow-up of technetium-99m-HMPAO SPECT in mild head injury. Journal of Nuclear Medicine. 1996; 37: 1605-09.

Jeret JS, Mandell M, Anziska B. Clinical predictors of abnormality disclosed by computed tomography after mild head trauma. Neurosurgery 1993; 32: 9-16.

Johnson PD, Hertal J, Olmsted LC. Effects of mild brain injury on an instrumented agility task. Clinical Journal of Sport Medicine 2002; 12: 12-17.

Johnston KM, Lassonde M, Ptito A. A contemporary neurosurgical approach to sport-related head injury: the McGill Concussion Protocol. Journal of the American College of Surgery 2001; 192: 515-524.

Kant R, Smith-Seemiller L, Isaac G, Duffy J. Tc-HMPAO SPECT in persistent post-concussion syndrome after mild head injury: comparison with MRI/CT. Brain Injury 1997; 11: 115-24.

Kay T, Newman B, Cavallo M. Toward a neuropsychological model of functional disability after mild traumatic brain injury. Neuropsychology 1992; 6: 371-384.

Kelsey JL, Thompson WD, Evans AS. *Methods in observational epidemiology,* New York, Oxford Press, 1986.

Kilgore JM. An investigation of the effects of short-term injuries on psychological readiness for competition. Microform publications, University of Oregon Eugene, Or., 1998.

King NS, Crawford S, Wenden FJ. The Rivermead Post Concussion Symptoms questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. Journal of Neurology 1995; 242: 587-92.

King NS, Crawford S, Wenden FJ, Caldwell FE, Wade DT. Early prediction of persisting post-concussion symptoms following mild and moderate head injuries. Br J Clin Psychol 1999; 38: 15-25.

King NS, Crawford S, Wenden FJ, Moss NEG, Wade DT. Interventions and service need following mild moderate head injury. Clinical Rehabilitation 1997; 11: 13-27.

Kino-Québec. *L'activité physique, déterminant de la santé des jeunes, avis du comité scientifique de Kino-Québec*, Secrétariat au loisir et au sport, ministère de la Santé et des Services sociaux, Gouvernement du Québec, 2000.

Klapp ST, Wyatt EP. Motor programming within a sequence of responses. Journal of Motor Behavior 1976; 14: 46-56.

Klonoff H, Clark C, Klonoff PS. Long term outcome of head injuries: a 23 year follow up study of children with head injuries. Journal of Neurology, Neurosurgery and Psychiatry 1993; 56: 410-415.

Klonoff H, Low MD, Clark C. Head injuries in children: a prospective five year follow-up. Journal of Neurology, Neurosurgery and Psychiatry 1977; 40: 1211-1219.

Knights RM, Ivan LP, Ventureya EC. The effects of head injury in children on neuropsychological and behavioural functioning. Brain Injury 1991; 5: 339-51.

Kraus JF, Black MA, Hessol N, Ley P, Rokaw W, Sullivan C, Bowers S, Knowlton S, Marshall L. The incidence of acute brain injury and serious impairment in a defined population. American Journal of Epidemiology 1984; 119: 186-201.

Kraus JF, Fife D, Conroy C. Pediatric brain injuries: the nature,c linical course and deadly outcomes in a defined United States population. Pediatrics 1987; 79: 501-507.

Kraus JF, McArthur DL, Silberman TA. Epidemiology of mild brain injury. Seminars in Neurology 1994; 14: 1-7.

Kraus JF, Rock A, Hemyari P. Brain Injuries among infants, children, adolescents and young adults. American Journal of Diseases in Children 1990; 144: 684-91.

Lemmon J, Keatley MA, Carnes J, Acimovic ML, Josephs E, Purvis J. Mild traumatic brain injury, Psychological Factors and the Effects of the Medico-Legal System on Recovery. The Journal of Cognitive Rehabilitation 1995; 4-11.

Levin HS, Aldrich EF, Saydjari C, Eisenber HM, Foulkes MA, Bellefleur M, Luerssen TJ, Jane JA, Marmarou A, Marshall LF, Young HF. Severe head injury in children: experience of the traumatic coma data bank. Neurosurgery 1992; 31: 435-444.

Levin HS, Amparo E, Eisenberg HM. Magnetic resonance imaging and computerized tomography in relation to the neurobehavioral sequelae of mild and moderate head injuries. Journal of Neurosurgery 1987; 66: 706-713.

Levin HS, Eisenberg HM. Neuropsycholological outcome of closed head injury in children and adolescents. Childs Brain 1979; 5: 281-92.

Levin HS, High W, Ewing-Cobbs L, Fletcher JM, Eisenberg HM, Miner ME, Goldstein F. Memory functioning during the first year after closed head injury in children and adolescents. Neurosurgery 1988; 22: 1043-1052.

Levin HS, Mattis S, Ruff RM, Eisenberg H, Marshall L, Tabaddor K, High W, Frankowski R. Neurobehavioral outcome following minor head injury: a three center study. Journal of Neurosurgery 1987; 66: 234-243.

Levin HS, Williams DH, Eisenberg HM, High WM, Guinto FC. Serial MRI and neurobehavioral findings after after mild to moderate head injury. Journal of Neurology Neurosurgery and Psychiatry 1992, 55:255-62.

Lishman WA. Physiogenesis and psychogenesis in the Post-concussional syndrome. Br J Psychiatry 1988; 153: 460-469.

Mackay RP. Post-traumatic neurosis. Industrial Medicine and Surgery 1960; 29: 200-203.

Macpherson JM. How flexible are muscle synergies? In: Humphrey DR, Freund HJ (eds). *Motor control: concepts and issues*. New York, NY, John Wiley and sons Inc., 1991; 33-49.

Maki BE, McIlroy WE. Influence of arousal and attention on the control of postural sway. Journal of Vestibular Research: Equilibrium and Orientation 1996; 6: 53-9.

Mandel S. Minor head injury may not be "minor". Post-graduate Medicine 1989; 85: 213-225.

Marion DW. Outcome from severe head injury. In. Narayan, R.K., Wilberger, J.E.jr, Povlishock, J.T. (eds), *Neurotrauma*, McGraw Hill Cies inc, 1996: 767-777.

Mattson AJ, Levin HS Evankovich KE. Longitudinal assessment of memory and motor skills after mild closed head injury in children and adolescents. Journal of Clinical Experimental Neuropsychology 1990; 12: 104.

McKiddie B, Maynard IW. Perceived competence of schoolchildren in physical education. Journal of Teaching in Physical Education 1997; 16: 324-339.

Merskey H, Woodforde JM. Psychiatric sequelae of minor head injury. Brain 1972; 95: 521-528.

Middleboe T, Anderson HS, Birket-Smith M. Minor head injury: impact on general health after one year. A prospective follow-up study. Acta Neurologica Scandinavia 1992; 85: 5-9.

Mild Traumatic Brain Injury committee (American Congress of Rehabilitation Medecine, Head Injury Interdisciplinary Special Interest Group): Journal of Head Trauma Rehabilitation, 1993; 8: 86-87.

Miller H. Accident neurosis. British Medical Journal 1961; 1: 919-925, 992-998.

Miller JD, Jones PA. Minor head injury in rehabilitation of the adult and child with traumatic brain injury. In Rosenthal M., Bond, M.R., Griffith, E.R., Miller, J.D., (eds) .: *Rehabilitation of the adult and child with traumatic brain injury*,2nd edition, F.A. Davis Co, Philadelphia, 1990; 236-250.

Miller L. Neuropsychology and pathophysiology of mild head injury and the post-concussion syndrome: clinical and forensic considerations. The Journal of Cognitive Rehabilitation 1996; 15: 8-23.

Mittl RL, Grossman RI, Hiele JF, Hurst RW, Kauder DR, Gennarelli TA, Alburger GW. Prevalence of MR evidence of diffuse axonal injury in patients with mild head injury and normal head CT findings. AJNR American Journal of Neuroradialogy 1994;15: 1583-89.

Montgomery EA, Fenton GW, McLelland RJ, MacFlynn G, Rutherford WH. The psychobioloby of minor head injury. Psychological Medicine 1991; 21: 375-384.

Mrazic M, Ferrara MS, Peterson CL, Elliott RE, Courson RW, Clanton MDI. Injury severity and neuropsychological and balance outcomes of four college athletes. Brain Injury 2000; 14: 921-31.

Multi-society task force on PVS.: Medical aspects of the persistent vegetative state, part I New England Journal of Medicine 1994; 330: 1499-1508.

Murray R, Shum D, McFarland K. Attentional deficits in head-injured children: an information processing analysis. Brain Cognition 1992; 18: 99-115.

Murshid WR. Role of skull radiography in the initial evaluation of minor head injury: a retrospective study. Acta Neurochirurgica 1994; 129: 11-14.

Nashner LM. Adapting reflexes controlling the human posture. Experimental Brain Research 1976; 26: 59-72.

Nashner LM. Fixed patterns of rapid postural responses among leg muscles during stance. Experimental Brain Research 1977; 30: 13-24.

Nashner LM, Berthoz A. Visual contribution to rapid motor responses during posture control. Exp Brain Res 1978; 150: 403-407.

Nashner LM, Black FO, Wall, C. Adaptation to altered support and visual conditions during stance: patients with vestibular deficits. J Neuroscience 1982; 2: 536-544.

Nashner LM, McCollum G. The organization of human postural movements: a formal basis and experimental synthesis. Behav Brain Sci 1985; 8: 135-172.

Nolin P, Mathieu F. Déficits de l'attention et de la vitesse du traitement de l'information chez des enfants ayant subi un traumatisme crâniocérébral léger. Annales de Réadaptation et Médecine Physique 2000; 43: 236-45.

Norril ML. Effects of movement complexity on choice reaction and movement times. Research Quarterly 1974; 45: 154-161.

Oppenheimer DR. Microscopic lesions in the brain following head injury. Journal of Neurology, Neurosurgery and Psychiatry 1968; 14: 8-18.

Orrison WW, Gentry LR, Stimac GK, Tarrel RM, Espinosa MC, Cobb LC. Blinded comparison of cranial CT and MR in closed head injury evaluation. American Journal of Neuroradiology 1994; 6: 15-22.

Overgoard J, Molsdal C, Tweed WA. Cerebral circulation after head injury part 3: Does reduced regional blood flow determine recovery of brain function after blunt head injury. Journal of Neurosurgery 1981; 55: 63-74.

Paniak C, Toller-Lobe G, Durand A, Nagy J. A randomized trial of two treatments for mild traumatic Brain Injury 1998; 12: 1011-1023.

Parasuraman R, Mutter SA, Molloy R. Sustained attention following mild closed head injury. Journal of clinical and experimental neuropsychology 1991; 13: 789-811.

Polivshock JT, Becker DP, Cheng CLY. Axonal change in minor head injury. Journal of Neuropathology and Experimental Neurology. 1986; 42: 225-242.

Ponsford J, Kinsella G. Attentional deficits following closed-head injury. Journal of Clinical and Experimental Neuropsychology 1992; 14: 822-38.

Ponsford J. Willmott C. Rothwell A. Cameron P. Ayton G. Nelms R. Curran C. Impact of early intervention on outcome after mild traumatic brain injury in children. Pediatrics. 2001: 108:1297-303.

Ponsford J, Willmott C; Rothwell A; Cameron P, Ayton G, Nelms R; Curran C, Ng Kim T. Cognitive and Behavioral Outcome Following Mild Traumatic Head Injury in Children. Journal of Head Trauma Rehabilitation 1999; 14: 360–372.

Riach CL, Hayes KC. Anticipatory postural control in children. Journal of Motor Behavior 1990; 22: 250-266.

Roper SN, Mena I, King WA, Schweitzer J, Garrett K, Mehringer CM, McBride D. An analysis of cerebral blood flow in acute closed-head injury using technetium-99m-HMPAO SPECT and computed tomography. Journal of Nuclear Medicine 1991; 32: 1684-1687.

Rosenbaum DA. Successive approximations to a model of human motor programming. In: Bower GH, *Psychology of learning and motivation: Advances in research and theory* (vol.21) New York: Academic Press, 1988 254-96.

Ruijs MBM, Gabreëls FJM, Thijssen HOM. The utility of electroencephalography and cerebral computed tomography in children with mild and moderatly severe closed head injuries. Neuropediatrics 1994; 25: 73-77.

Rutherford WH, Merrett JD, McDonald JR. Symptoms at one year following concussion from minor head injury. Injury 1979; 10: 225-230.

Sallis JF, Patterson TL, Buono MJ, Nader PR. Relation of cardiovascular fitness and physical activity to cardiovascular disease risk factors in children and adults. American Journal of Epidemiology 1988; 127: 933-941.

Satz P, Zaucha K, McCleary C, Light R, Asarnow R, Becker D. Mild head injury in children and adolescents: a review of studies (1970-1995). Psychological Bulletin 1997; 122: 107-131.

Schmidt RA. *Motor control and learning: a behavioral emphasis.* 2nd ed. Champaign, Ill: Human Kinetics Inc; 1988.

Schunk DH. The self-efficacy perspective on achievement behavior. Education Psychologist 1984; 19: 119-218.

Schwartz CE, Coulthard-Morris L, Zeng Q, Retzlaff P. Measuring self-efficacy in people with multiple sclerosis: a validation study. Archives of Physical Medicine and Rehabilitation 1996; 77: 394-98.

Segalowitz SJ, Brown D. Mild head injury as a source of developmental disabilties. Journal of Learning Disabilities 1991; 24: 551-59.

Servadei F, Nanni A, Nasi MT. Evolving brain lesions in the first 12 hours after head injury: analysis of 37 comatose patients. Neurosurgery. 1995;37:899-907

Shum DHK, McFarland K, Bain JD. Effects of closed-head injury on attentional processes: an information-processing stage analysis. Journal of Clinical and Experimental Neuropsychology 1990; 12: 247-64.

Shumway-Cook A, Olmscheid R. A systems analysis of postural dyscontrol in traumatically brain injured patients. Journal of Head Trauma Rehabilitation 1990; 5: 51-62.

Shumway-Cook A, Woollacott M: Dynamics of Postural Control in the child with Down Syndrome. Physical Therapy 1985; 65:1315-1321.

Sidaway B, Christina RW, Shea JB. A movement constraint interpretation of the response complexity effect on programming time. In Colley AM, Beech, JR (Eds). *Cognition and action in skilled behaviour. Advances in psychology*, 1988; 87-102.

Smith AM, Scott SG, Young ML. The emontional responses of athletes to injury. Mayo clinics Proceedings 1990; 65: 38-50.

Stablum F, Leonardi G, Mazzoldi M. Attention and control deficits following closed head injury. Cortex 1994; 30: 603-18.

Stein SC. Classification of head injury. In. Narayan, R.K., Wilberger, J.E.jr, Povlishock, J.T. (eds), *Neurotrauma,* McGraw Hill Cies inc, 1996: 31-40.

Sternberg S. On the discovery of the processing stage. Acta Psychologica 1969; 30: 276-315.

Stiell IG, Wells GA, Vandemheen K, Laupacis A, Brison R, Eisenhauer MA, Greenberg GH, MacPhail I, McKnight RD, Reardon M, Verbeek R, Worthington J, Lesiuk H. variation in ED use of computed tomography for patients with minor head injury. Annals of Emergency Medicine 1997; 30: 14-22.

Stoffregen TA. Flow structure versus retinal location in the optical control of stance. Journal of Experimental Psychology 1985; 11: 554-565.

Stokx LC, Gaillard WK. Task and driving performance of patients with a severe concussion of the brain. Journal of Clinical and Experimental Neuropsychology 1986; 8: 421-36.

Strauss, I., Savitsky, N.: Head Injury, neurological and psychiatric aspects. Archives of Neurology and Psychiatry 1934; 31: 893-955.

Sullivan TE, Schefft BK, Warm JS, Dember WN. Closed head injury assessment and research methodology. Journal of Neuroscience Nursing 1994; 29: 24-29.

Swaine BR, Friedman DS. Activity restrictions as part of the discharge management for children with a traumatic brain injury. Journal of Head Trauma Rehabilitation 2001; 16: 292-301.

Swaine B, Marosi E. Exploring the possible association between previous head injury and head injury among children. Acta Neurochirurgica 2002; 144: A34-45.

Szymanski HV, Linn R. A Review of the postconcussion syndrome. International Journal of Psychiatry in Medecine 1992; 22: 357-375.

Tolfts A, Stiller K. Do patients with traumatic brain injury benefit from physiotherapy? A review of the evidence. Physiotherapy Theory & Practice 1997; 13:197-206.

Umile EM, Plotkin RC, Sandel ME. Functional assessment of mild traumatic brain injury using SPECT and neuropsychological testing. Brain Injury. 1998; 12: 577-594.

Van Zomeren AH, Brouwer WH. *Clinical neuropsychology of attention.* New York: Oxford University Press, 1994.

Vasquez Barquero A, Vasquez Barquero JL, Austin O. The epidemiology of head injury in Catabria. European Journal of Epidemiology 1992; 8: 832-937.

Vollmer DG, Torner JC, Jane JA. Age and outcome following traumatic coma: why do older patients fare worse? Journal of Neurosurgery 1991; 75: S37-49.

Wade DT, King NS, Wenden FJ, Crawford S, Caldwell FE. Routine follow-up after haed injury: a second randomised controlled trial. J Neurol Neurosurg Psychiatry 1998; 65: 177-183.

Wade MG, Jones G. The role of vision and spatial orientation in the maintenance of posture. Physical Therapy 1997; 77: 619-628.

Wade LD, Canning CG, Fowler V, Felmingham KL, Baguley IJ. Changes in postural sway and performance of functional tasks during rehabilitation after traumatic brain injury. Archives of Physical Medicine and Rehabilitation 1997; 78: 1107-11.

Wallace BE, Wagner AK, Wagner EP, McDeavitt JT. A history and review of quantitative electroencephalography in traumatic brain injury. Journal of Head Trauma Rehabilitation. 2001; 16: 165-190.

Weiss MR, Troxel RK. Psychology of the injured athlete. Athletic Training 1986; 154: 104-9.

Westcott SL, Crowe TK, Deitz JC, Richardson P. Test-retest reliability of the pediatric clinical test of sensory interaction for balance. Physical and Occupational Therapy in Pediatrics 1994; 14: 1-22.

Wolfson LI, Whipple R, Amerman P. Stressing the postural response: a quantitative method for testing balance. Journal of the American geriatric Society 1986; 34: 845-850.

Woollacott MH, Shumway-Cook A. Concepts and methods for assessing postural instability. Journal of Aging and Physical Activity 1996; 4: 214-233.

Woollacott, MH, Shumway-Cook, A., Williams, H.G.: The development of posture and balance control in children. In Woollacott, M.H., Shumway-Cook, A. (eds), *Development of posture and gait across the life span*. Columbia, SC, University of South Carolina Press, 1989.

Wrightson P, McGinn V, Gronwall D. Mild head injury in preschool children: evidence that it can be associated with a persisting cognitive defect. Journal of Neurology Neurosurgery and Psychiatry 1995; 59: 375-380.

Zacharias G, Young L. Influence of combined visual and vestibular cues on human perception and control of horizontal rotation. Experimental Brain Research 1981; 41: 159-171.

Zahn TP, Mirsky AF. Reaction time indicators of attention deficits in closed head injury. Journal of Clinical and Experimental Neuropsychology 1999; 21: 353-67.

ANNEXE A

Recommandations pour la reprise des activités suite au TCL chez l'enfant

The Montreal Children's Hospital

Pediatric & Adolescent Neurotrauma Program

Recommendations for activity restrictions

☐ 1 week **☐ 2 weeks** **☐ 4 weeks** **☐__ weeks**

The following restrictions are important to allow for an adequate healing period, and reduce the chance of having another head injury during this time. The restrictions should help in reducing persistent post head injury headache, dizziness, visual disturbances, poor attention span, excessive fatigue, and in some cases seizures.

For children of all ages

- Inform the teachers, and coaches of the head injury & restrictions
- No gym, contact sports, and other strenuous activities
- Adequate rest and breaks are encouraged
- A gradual return to school (half days for the 1st week) or short term modification of the workload may be indicated if symptoms persist
- Supervision in the classroom and on the playground at recess & lunch
- Limit time spent on video games, computers, and television as these activities may provoke increased headaches
- Avoid movies in large screen theatres as the lights & sounds may be overwhelming
- Supervised swimming is permitted but no diving or jumping into the water
- When returning to sports & recreational activities REMEMBER to wear appropriate protective head gear and equipment at all times!
- Following the period of restriction the return to physical activity should be done gradually
- You should be completely free of symptoms for the entire last week of the restricted period before returning to all activities.

Additional recommendations for adolescents

- Absolutely no drugs or alcohol
- Avoid frequenting bars/pubs due to the excessive amount of noise, lights, smoke, etc. which again may provoke headaches
- Other specific restrictions include________________________

ANNEXE B

Lettres d'explication des études aux parents et enfants

B.1 Projet de recherche principal

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Motor abilities in children after a mild head injury
Information sheet for parents

Reasons why this study is being done

Your child has sustained a mild head injury, or concussion, in the last few hours. The injury has been called mild because your child did not lose consciousness for a long time and the symptoms are fewer than the ones present in a more severe injury.

In a previous pilot study, we found that some of the children who sustained such an injury present with some deficits related to their motor function up to a few weeks after the injury. We are interested in studying the presence and nature of these deficits with a larger number of children and during a longer period of time.

Your required participation

We would like to evaluate your child 3 times over the next 3 months. We will assess your child's balance, response speed and level of physical activity. Each evaluation will take place in your home so you do not have to travel back and forth from the hospital. The activities are not painful or very demanding.

Your participation will help us learn more about the type of injury your child has sustained. We are at your service to answer any questions that you might have regarding the purpose of the study or the nature of the participation that will be required from you and your child should you choose to participate.

Thank you for taking the time to think about this study.

Isabelle Gagnon M.Sc.Pht
Physiotherapist
[redacted]

INSTITUTIONAL REVIEW BOARD
approved for 12 months
from date below
July 23/99
sig [redacted]

L'HÔPITAL DE MONTRÉAL POUR ENFANTS • THE MONTREAL CHILDREN'S HOSPITAL
2300 rue Tupper, Montréal (Québec) H3H 1P3 Tél.: (514) 934-4400

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Capacités motrices chez les enfants ayant subi un TCE léger
Informations aux parents

Raisons de l'étude

Aux cours des dernières heures, votre enfant a subi un traumatisme crânio-encéphalique léger ou commotion cérébrale. Le traumatisme a été classé comme léger car la perte de conscience a été de courte durée et les symptômes qu'il démontre sont de gravité moindre que ceux présents lors d'un traumatisme plus sévère.

Lors d'une étude pilote, nous avons trouvé que certains des enfants ayant subi un tel traumatisme présentent des déficits moteurs quelques semaines après le traumatisme. Nous voulons étudier plus en profondeur la présence et la nature de ces déficits et nous voulons aussi documenter si ces déficits persistent, avec un plus grand nombre d'enfants,

Participation requise

Nous aimerions évaluer votre enfant à 3 reprises au cours des 3 prochains mois. Nous évaluerons son équilibre et sa vitesse de réponse motrice à l'aide de divers tests et le questionnerons sur son niveau d'activité physique. Toutes les évaluations auront lieu à votre domicile afin de minimiser vos déplacements. Les activités ne seront pas douloureuses ni très exigeantes.

Nous vous proposons de participer à cette recherche qui servira à établir de nouvelles connaissances sur le type de blessure qu'a subi votre enfant. Nous sommes disponibles à répondre à toutes vos questions sur les raisons de l'étude, et sur la nature de votre participation.

Merci de l'attention que vous porterez à cette proposition,

Isabelle Gagnon M.Sc.pht
physiothérapeute
[redacted]

INSTITUTIONAL REVIEW BOARD
approved for 12 months
July 23/99
signed [redacted]

L'HÔPITAL DE MONTRÉAL POUR ENFANTS • THE MONTREAL CHILDREN'S HOSPITAL
2300 rue Tupper, Montréal (Québec) H3H 1P3 Tél.: (514) 934-4400

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Motor abilities in children after a mild head injury
Information sheet for parents of the control child

Reasons why this study is being done

Your child's friend ________________________, has sustained a mild head injury, or concussion, a few hours ago. The injury has been called mild because the child did not lose consciousness for a long time and the symptoms are fewer than the ones present in a more severe injury.

In a previous pilot study, we found that some of the children who sustained such an injury present with some deficits related to their motor function up to a few weeks after the injury. We are interested in studying the presence and nature of these deficits with a larger number of children and during a longer period of time and to compare the motor function with that of uninjured children.

Your required participation

We would like to evaluate your child 3 times over the next 3 months. We will assess your child's balance, response speed and level of physical activity. Each evaluation will take place in your home so you do not have to travel back and forth from the hospital. The activities are not painful or very demanding.

Your participation will help us learn more about the type of injury your child's friend has sustained. We are at your service to answer any questions that you might have regarding the purpose of the study or the nature of the participation that will be required from you and your child should you choose to participate.

Thank you for taking the time to think about this study.

Isabelle Gagnon M.Sc.Pht
Physiotherapist
[redacted]

INSTITUTIONAL REVIEW BOARD
approved for 12 months
July 23/99
[redacted]
signed

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié a la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Capacités motrices chez les enfants ayant subi un TCE léger
Informations aux parents de l'enfant contrôle

Raisons de l'étude

Aux cours des dernières heures, l'ami de votre enfant a subi un traumatisme crânio-encéphalique léger ou commotion cérébrale. Le traumatisme a été classé comme léger car la perte de conscience a été de courte durée et les symptômes qu'il démontre sont de gravité moindre que ceux présents lors d'un traumatisme plus sévère.

Lors d'une étude pilote, nous avons trouvé que certains des enfants ayant subi un tel traumatisme présentent des déficits moteurs quelques semaines après le traumatisme. Nous voulons étudier plus en profondeur la présence et la nature de ces déficits et nous voulons aussi documenter si ces déficits persistent, avec un plus grand nombre d'enfants, et comparer la performance avec celle des enfants n'ayant pas subi un tel traumatisme.

Participation requise

Nous aimerions évaluer votre enfant à 3 reprises au cours des 3 prochains mois. Nous évaluerons son équilibre et sa vitesse de réponse motrice à l'aide de divers tests et le questionnerons sur son niveau d'activité physique. Toutes les évaluations auront lieu à votre domicile afin de minimiser vos déplacements. Les activités ne seront pas douloureuses ni très exigeantes.

Nous vous proposons de participer à cette recherche qui servira à établir de nouvelles connaissances sur le type de blessure qu'a subi l'ami de votre enfant. Nous sommes disponibles à répondre à toutes vos questions sur les raisons de l'étude, et sur la nature de votre participation.

Merci de l'attention que vous porterez à cette proposition,

Isabelle Gagnon M.Sc.pht
physiothérapeute
[redacted]

INSTITUTIONAL REVIEW BOARD
for 12 months
July 23/99
signed [redacted]

B.2 Projet de recherche PCTSIB/SOT

INFORMATION AUX PARENTS

Comparaison de la performance aux tests d'équilibre Balance Master et Pediatric Clinical Test of Sensory Interaction for Balance

Responsables:

Isabelle Gagnon pht M.Sc.
Étudiante au doctorat
CRIR
340-2085 poste 2058

Robert Forget pht, PhD
Directeur scientifique
CRIR
340-7050

Bonnie Swaine pht, PhD
Professeur adjoint
École de réadaptation
Université de Montréal
343-7361

Chers parents,

Nous aimerions vous proposer un projet de recherche pour lequel nous aurions besoin de la participation de votre enfant.

Il s'agit d'une étude visant à comparer la performance de votre enfant à deux tests d'équilibre, le Balance Master et le Pediatric Clinical Test of Sensory Interaction for Balance. Ce sont deux tests qui évaluent le maintien de l'équilibre sous différentes conditions telles debout les yeux fermés ou encore se tenir sur une jambe.

Les deux outils sont déjà utilisés par les cliniciens dans les hôpitaux ou les centres de réadaptation mais nous aimerions vérifier si les résultats aux deux tests sont comparables et équivalents.

Si vous et votre enfant acceptez de participer à cette étude, nous vous demanderons de vous déplacer à l'Institut de Réadaptation de Montréal pour une seule session d'évaluation d'une durée d'environ 45 minutes. L'horaire exact sera déterminé selon vos disponibilités.

Nous vous remercions à l'avance de l'attention que vous porterez à cette demande et sommes disponibles pour répondre à toutes vos questions.

ANNEXE C

Formulaires de consentement

C.1 Projet de recherche principal

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Informed Consent Form: Child with Head Injury

Motor Abilities of Children Having Sustained a Mild Head Injury

Neurotrauma Program, Montreal Children's Hospital, McGill University Health Center

Investigators:

Isabelle Gagnon M.Sc.pht
Staff physiotherapist
Montreal Children's Hospital, McGill
514-934-4407
PhD student
Université de Montréal

Robert Forget PhD
Associate Professor
Physiotherapy program
School of rehabilitation
Université de Montréal
514-343-5935

Bonnie Swaine PhD
Assistant Professor
Physiotherapy program
School of rehabilitation
Université de Montréal
514-343-7361

Deborah Friedman B.Sc.PT
Program Head, Neurotrauma Program
Montreal Children's Hospital
McGill University Health Center
514-934-4400

PARENT CONSENT

I, ______________________________, allow my child, ________________________, to participate in this study

Your child has sustained a mild head injury, or concussion, in the last few hours. The injury has been called mild because your child did not lose consciousness for a long time (no more than 30 minutes) and the symptoms are fewer than the ones present in a moderate or severe injury. In a previous pilot study, we have found that some of the children who sustained such an injury present with some deficits related to their motor function up to a few weeks after the injury. We are interested in studying the presence and nature of these deficits with a larger number of children and during a longer period of time.

The purpose of the study proposed is to evaluate the motor abilities of your child using various measures of balance, response speed, and physical activity level. The tests will include activities such as standing on one foot, touching pressure switches in response to light signals and answering questions regarding level of physical activity. This study will include 3 evaluations (at 1, 4 and 12 weeks after the trauma). Each evaluation will last around 90 minutes. These will be held in your home to minimize your travelling. The results of this study will help us learn more about the type of injury that your child sustained.

I was informed in an appropriate manner of the nature of my child's participation in this study.

I am aware that no medication is to be given, or invasive procedures performed, and that the tests administered are to evaluate motor abilities. I understand that the tests are simple and will not be painful in any way.

I am aware that the testing will consist of 3 sessions of 90 minutes each to be held at our home.

I allow the investigator access to my child's medical record for scientific and professional purposes. I also allow the investigators to contact my child's physical education teacher in order to investigate physical performance.

I allow the balance testing to be videotaped. The videotape will only be used for data analysis, and unless you provide separate consent for its use for educational purposes, it will be destroyed after data analysis is completed, in June 2001.

I understand that confidentiality will be respected. The results of this research project may be communicated to the scientific community, but the identity of my child will not be revealed.

I understand that my child is free to discontinue his/her participation in the study at any time, and this will not affect his/her follow-up or eventual treatment in any way.

The investigator will be available after the evaluation to discuss the results obtained if I wish to do so.

Parent's signature: ______________________ Date: ______________

Investigator's signature: __________________ date: ________________

Witness' signature: ____________________ date: ________________

INSTITUTIONAL REVIEW BOARD
approved [illegible] 12 months
from July 23/99

[redacted]

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilie a la Faculté de medecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

CHILD CONSENT FORM

I, ______________________________, agree to participate in the study:

Motor abilities of children having sustained a mild head injury

I understand what my participation will be and I am aware that I can discontinue my participation at any time.

I understand that the tests I am going to take will not be painful and only involve evaluation of my motor skills.

Child's signature: ________________________ date: ___________________

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Formulaire de consentement éclairé: enfant avec traumatisme

Habiletés motrices des enfants ayant subi un traumatisme crânio-cérébral léger

Neurotraumatologie, Hôpital de Montréal pour Enfants, Centre de santé de l'université McGill

CHERCHEURS RESPONSABLES:

Isabelle Gagnon M.Sc.pht
Physiothérapeute
Hôpital de Montréal pour enfants,
Centre de Santé de l'Université McGill
514-934-4407
PhD student
Université de Montréal

Robert Forget PhD
Professeur associé
Physiothérapie
École de réadaptation
Université de Montréal
514-343-5935

Bonnie Swaine PhD
Assistant Professeur
Physiothérapie
École de réadaptation
Université de Montréal
514-343-7361

Deborah Friedman B.Sc.PT
Chef de programme, programme de Neurotraumatologie
Hôpital de Montréal pour enfants,
Centre de Santé de l'Université McGill
514-934-4400

CONSENTEMENT DES PARENTS

Je ______________________, autorise mon enfant, ________________________ à participer au projet de recherche intitulé:

Habiletés motrices des enfants ayant subi un traumatisme crânio-cérébral léger

Aux cours des dernières heures, votre enfant a subi un traumatisme crânio-encéphalique léger ou commotion cérébrale. Le traumatisme a été classé comme léger car la perte de conscience a été de courte durée (moins de 30 minutes) et les symptômes qu'il démontre sont de gravité moindre que ceux présents lors d'un traumatisme plus sévère. Lors d'une étude pilote, nous avons trouvé que certains des enfants ayant subi un tel traumatisme présentent des déficits moteurs quelques semaines après le traumatisme. Nous voulons étudier plus en profondeur la présence et la nature de ces déficits et nous voulons aussi documenter si ces déficits persistent, avec un plus grand nombre d'enfants.

Le but de cette étude est d'évaluer la performance motrice de votre enfant en utilisant diverses mesures d'équilibre, de vitesse de réponse motrice et de niveau d'activité physique. Les tests incluront des activités telles se tenir sur un pied, toucher des plaques de pression en réponse à des stimuli lumineux, et répondre à des questions en regard des activités physiques. Cette étude comprendra 3 sessions d'évaluation (à 1, 4 et 12 semaines post-trauma). Chacune des sessions durera environ 90 minutes et se tiendra à votre domicile pour minimiser vos déplacements. Les résultats seront ensuite utilisés pour établir de nouvelles connaissances sur le type de traumatisme qu'a subi votre enfant.

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Je reconnais avoir été informé de façon satisfaisante sur la nature de la participation de mon enfant à cette étude

Je suis informé qu'aucun médicament ou technique invasive ne seront utilisés et que le test a pour but d'évaluer la performance motrice. J'ai pris connaissance des procédures d'administration du test et je comprend que le tout sera fait sans douleur.

Je reconnais que la participation de mon enfant sera de 3 sessions de 90 minutes chacune se tenant à notre domicile.

J'accepte que les personnes responsables de l'étude aient un accès au dossier de mon enfant et que les informations recueillies soient utilisées à des fins scientifiques et professionnelles. J'autorise les chercheurs à contacter le professeur d'éducation physique de mon enfant afin d'investiguer la performance de mon enfant.

J'accepte que la partie équilibre des tests sera filmée. La cassette ne sera utilisée que pour des fins d'analyse à moins d'un consentement séparé à son utilisation pour des sessions d'éducation. Elle sera détruite après la fin des analyses, en juin 2001.

Je comprend que l'anonymat sera respecté à l'égard de mon enfant. Les résultats de cette étude pourront être communiqués à la communauté scientifique mais que l'identité de mon enfant ne sera pas révélée.

Il est aussi entendu que mon enfant peut se retirer du projet en tout temps et que la qualité de son suivi et de ses traitements éventuels n'en sera pas affectée.

La responsable de l'étude sera disponible, si je le désire, pour discuter des résultats après l'évaluation.

Signature du parent: ______________________ date: ____________

Signature de la responsable: ________________ date: ____________

Signature d'un témoin: ____________________ date: ____________

INSTITUTIONAL REVIEW BOARD
approv[illegible] months
from July 23/99

[redacted]

CONSENTEMENT DE L'ENFANT

Je, ______________________________ (nom de l'enfant), suis d'accord pour participer à l'étude intitulée:

Habiletés motrices des enfants ayant subi un traumatisme crânio-cérébral léger

Je comprend ce que je devrai faire et que je peux décider de ne plus participer à n'importe quel moment.

Je comprend que le test auquel je devrai participer se fera sans douleur et comprendra seulement des évaluations de mes habiletés motrices

Signature de l'enfant: __________________________ date:__________________

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Informed Consent Form: control child

Motor Abilities of Children Having Sustained a Mild Head Injury

Neurotrauma Program, Montreal Children's Hospital, McGill University Health Center

INVESTIGATORS:

Isabelle Gagnon M.Sc.pht
Staff physiotherapist
Montreal Children's Hospital, McGill
514-934-4407
PhD student
Université de Montréal

Robert Forget PhD
Associate Professor
Physiotherapy program
School of rehabilitation
Université de Montréal
514-343-5935

Bonnie Swaine PhD
Assistant Professor
Physiotherapy program
School of rehabilitation
Université de Montréal
514-343-7361

Deborah Friedman B.Sc.PT
Program Head, Neurotrauma Program
Montreal Children's Hospital
McGill University Health Center
514-934-4400

PARENT CONSENT

I, ______________________________, allow my child, ________________________, to participate in this study

Your child's friend, _________________________ has sustained a mild head injury, or concussion, in the last few hours. The injury has been called mild because the child did not lose consciousness for a long time (no more than 30 minutes) and the symptoms are fewer than the ones present in a moderate or severe injury. In a previous pilot study, we have found that some of the children who sustained such an injury present with some deficits related to their motor function up to a few weeks after the injury. We are interested in studying the presence and nature of these deficits with a larger number of children and during a longer period of time and to compare it to that of children who have not sustained this injury.

The purpose of the study proposed is to evaluate the motor abilities of your child using various measures of balance, response speed, and physical activity level. The tests will include activities such as standing on one foot, touching pressure switches in response to light signals and answering questions regarding level of physical activity. This study will include 3 evaluations (at 1, 4 and 12 weeks after the trauma). Each evaluation will last around 90 minutes. These will be held in your home to minimize your travelling. The results of this study will help us learn more about the type of injury that the child sustained.

I was informed in an appropriate manner of the nature of my child's participation in this study.

I am aware that no medication is to be given, or invasive procedures performed, and that the tests administered are to evaluate motor abilities. I understand that the tests are simple and will not be painful in any way.

I am aware that the testing will consist of 3 sessions of 90 minutes each to be held at our home.

I allow the investigator access to my child's medical record for scientific and professional purposes. I also allow the investigators to contact my child's physical education teacher in order to investigate physical performance.

I allow the balance testing to be videotaped. The videotape will only be used for data analysis, and unless you provide separate consent for its use for educational purposes, it will be destroyed after data analysis is completed, in June 2001.

I understand that confidentiality will be respected. The results of this research project may be communicated to the scientific community, but the identity of my child will not be revealed.

I understand that my child is free to discontinue his/her participation in the study at any time.

The investigator will be available after the evaluation to discuss the results obtained if I wish to do so.

Parent's signature: ______________________ Date: ______________

Investigator's signature: __________________ date: ________________

Witness' signature: ____________________ date: ________________

INSTITUTIONAL REVIEW BOARD
approved for 12 months
from date below
July 23/99

[redacted]

CHILD CONSENT FORM

I, _______________________________, agree to participate in the study:

Motor abilities of children having sustained a mild head injury

I understand what my participation will be and I am aware that I can discontinue my participation at any time.

I understand that the tests I am going to take will not be painful and only involve evaluation of my motor skills.

Child's signature: _________________________ date: ____________________

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montreal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Formulaire de consentement éclairé: enfant contrôle

Habiletés motrices des enfants ayant subi un traumatisme crânio-cérébral léger

LIEU: Neurotraumatologie, Hôpital de Montréal pour Enfants,
Centre de santé de l'université McGill

CHERCHEURS RESPONSABLES:

Isabelle Gagnon M.Sc.pht
Physiothérapeute
Hôpital de Montréal pour enfants,
Centre de Santé de l'Université McGill
514-934-4407
PhD student
Université de Montréal

Robert Forget PhD
Professeur associé
Physiothérapie
École de réadaptation
Université de Montréal
514-343-5935

Bonnie Swaine PhD
Assistant Professeur
Physiothérapie
École de réadaptation
Université de Montréal
514-343-7361

Deborah Friedman B.Sc.PT
Chef de programme, programme de Neurotraumatologie
Hôpital de Montréal pour enfants,
Centre de Santé de l'Université McGill
514-934-4400

CONSENTEMENT DES PARENTS

Je ________________________, autorise mon enfant, ___________________________ à participer au projet de recherche intitulé:
Habiletés motrices des enfants ayant subi un traumatisme crânio-cérébral léger

Aux cours des dernières heures, l'ami de votre enfant, _________________________ a subi un traumatisme crânio-encéphalique léger ou commotion cérébrale. Le traumatisme a été classé comme léger car la perte de conscience a été de courte durée (moins de 30 minutes) et les symptômes qu'il démontre sont de gravité moindre que ceux présents lors d'un traumatisme plus sévère. Lors d'une étude pilote, nous avons trouvé que certains des enfants ayant subi un tel traumatisme présentent des déficits moteurs quelques semaines après le traumatisme. Nous voulons étudier plus en profondeur la présence et la nature de ces déficits et nous voulons aussi documenter si ces déficits persistent, avec un plus grand nombre d'enfants et comparer celle-ci avec des enfants qui n'ont pas subi de tels traumatismes.

Le but de cette étude est d'évaluer la performance motrice de votre enfant en utilisant diverses mesures d'équilibre, de vitesse de réponse motrice et de niveau d'activité physique. Les tests incluront des activités telles se tenir sur un pied, toucher des plaques de pression en réponse à des stimuli lumineux, et répondre à des questions en regard des activités physiques. Cette étude comprendra 3 sessions d'évaluation (à 1, 4 et 12 semaines post-trauma). Chacune des sessions durera environ 90 minutes et se tiendra à votre domicile pour minimiser vos déplacements. Les résultats seront ensuite utilisés pour établir de nouvelles connaissances sur le type de traumatisme qu'a subi l'ami de votre enfant.

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Je reconnais avoir été informé de façon satisfaisante sur la nature de la participation de mon enfant à cette étude

Je suis informé qu'aucun médicament ou technique invasive ne seront utilisés et que le test a pour but d'évaluer la performance motrice. J'ai pris connaissance des procédures d'administration du test et je comprend que le tout sera fait sans douleur.

Je reconnais que la participation de mon enfant sera de 3 sessions de 90 minutes chacune se tenant à notre domicile.

J'accepte que les personnes responsables de l'étude aient un accès au dossier de mon enfant et que les informations recueillies soient utilisées à des fins scientifiques et professionnelles. J'autorise les chercheurs à contacter le professeur d'éducation physique de mon enfant afin d'investiguer la performance de mon enfant.

J'accepte que la partie équilibre des tests sera filmée. La cassette ne sera utilisée que pour des fins d'analyse à moins d'un consentement séparé à son utilisation pour des sessions d'éducation. Elle sera détruite après la fin des analyses, en juin 2001.

Je comprend que l'anonymat sera respecté à l'égard de mon enfant. Les résultats de cette étude pourront être communiqués à la communauté scientifique mais que l'identité de mon enfant ne sera pas révélée.

Il est aussi entendu que mon enfant peut se retirer du projet en tout.

La responsable de l'étude sera disponible, si je le désire, pour discuter des résultats après l'évaluation.

Signature du parent: ______________________________ date: _________________

Signature de la responsable: ______________________ date: _________________

Signature d'un témoin: ___________________________ date:_________________

INSTITUTIONAL REVIEW BOARD
approved for 12 months
from July 23/99

[redacted]

C.2 Projet de recherche PCTSIB/SOT

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

Formulaire de consentement

Nom du participant:
Date de naissance:

Comparaison de la performance aux tests d'équilibre Balance Master et Pediatric Clinical Sensory Interaction Test for Balance

Responsables:

Isabelle Gagnon pht, M.Sc.
Étudiante au doctorat
Centre de Recherche Interdisciplinaire en Réadaptation
340-2085 poste 2058

Robert Forget pht, PhD
Directeur scientifique
Centre de Recherche Interdisciplinaire en Réadaptation
340-7050

Description du projet

Le projet de recherche proposé aujourd'hui vise à comparer la performance de votre enfant à deux tests d'équilibre afin de comparer sa performance aux deux tests. Les deux outils se nomment le Balance Master (BM) et le Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB). Les deux testent l'équilibre en plaçant l'enfant dans différentes situations telles les yeux fermés ou encore se tenir sur une jambe.

Nature de la participation

Il n'y aura qu'une seule séance d'évaluation. Lors de cette évaluation, nous demanderons à votre enfant de maintenir des positions différentes telles debout les yeux ouverts et fermés ou encore debout sur une plate-forme mobile pendant 20 à 30 secondes et la session d'évaluation aura une durée totale d'environ 45 minutes. Il n'y aura pas d'autres évaluations ce qui veut dire que vous n'aurez à vous déplacer qu'une seule fois. Les évaluations seront filmées afin de pouvoir aussi évaluer la qualité de la performance de votre enfant. Les cassettes seront détruites après la période d'analyse des données.

Avantages ou inconvénients personnels découlant de la participation de votre enfant

Votre enfant ne retirera aucun avantage spécifique pour sa participation à cette étude ni ne subira d'inconvénients autres que ceux causés par le déplacement au site d'évaluation. L'évaluation se fera sans douleur et ne présente aucun risque pour votre enfant puisqu'il sera retenu par un harnais style parachute dans le BM en cas de chute et que deux personnes se tiendront de chaque côté lors de l'évaluation clinique (PCTSIB).

Il est entendu que votre enfant peut se retirer de l'étude ou cesser l'évaluation à n'importe quel moment sans aucun préjudice.

Confidentialité

Tous les renseignements obtenus au sujet de votre enfant demeureront strictement confidentiels. L'utilisation de certaines données à des fins scientifiques ou d'enseignement sera faite dans l'anonymat le plus complet.

Consentement

La nature de l'étude, les procédés utilisés, les risques et les bénéfices que comportent ma participation à cette étude ainsi que le caractère confidentiel des informations recueillies au cours de l'étude m'ont été expliqués.

J'ai eu l'occasion de poser toutes les questions concernant les différents aspects de l'étude et de recevoir des réponses à ma satisfaction.

J'accepte volontairement de participer à cette étude. Je peux me retirer en tout temps sans préjudice d'aucune sorte.

Nom du parent ______________________ **Signature** ___________________________

Nom de l'enfant ______________________ **Signature** ___________________________

Nom du chercheur ___________________ **Signature** ___________________________

Nom du témoin ______________________ **Signature** ___________________________

Fait à _____________________________ **le** _____________, **2000**

INSTITUTIONAL REVIEW BOARD
[illegible]
[illegible]
Dec 12/00
[redacted]

ANNEXE D

Certificats d'éthiques

D.1 Projet de recherche principal

Centre universitaire de santé McGill
McGill University Health Centre

Le Centre universitaire de santé McGill (CUSM) comprend l'Hôpital de Montréal pour Enfants, l'Hôpital général de Montréal, l'Hôpital neurologique de Montréal et l'Hôpital Royal Victoria. Le CUSM est affilié à la Faculté de médecine de l'Université McGill.
The McGill University Health Centre (MUHC) consists of The Montreal Children's Hospital, The Montreal General Hospital, The Montreal Neurological Hospital, and The Royal Victoria Hospital. The MUHC is affiliated with the McGill University Faculty of Medicine.

THE INSTITUTIONAL REVIEW BOARD

A Montreal Children's Hospital Committee consisting of:

Jane McDonald, M.D., Chairperson	Microbiology
Gordon Watters, Co-chairperson	Neurology
Carol Schopflocher, M.A	Psychology
Hema Patel, M.D.	Pediatrics
Kathleen Glass, DCL	Ethicist/Lawyer
Sharon Abish, M.D.	Hematology
Janet Rennick, M.Sc.N.	Nursing
Donald Meloche, LTh	Pastoral Services

reviewed on June 21st, 1999 the clinical research project entitled:

Motor Abilities of Children Having Sustained a Mild Head Injury

submitted by: Isabelle Gagnon

and consider it to be within acceptable limits of clinical investigation solely from the point of view of medical ethics. The following conditions apply to the ethical approval of the above-named study:

1. Receipt of scientific approval by the McGill University/Montreal Children's Hospital Research Institute. Final approval of the IRB, i.e. the dated and signed IRB stamp on the French and English versions of the consent form will confirm scientific approval from the Research Institute.

2. The study is approved for a period of one year from the date shown below.

3. Prior to the end of the one-year period, the investigator(s) must advise the Institutional Review Board of the number and status of patients enroled in the study. We wish to be advised promptly of any significant adverse outcomes.

4. The investigator(s) must inform the Institutional Review Board should any changes be made to the study protocol and/or consent form.

5. The Montreal Children's Hospital Institutional Review Board has been designated by the Minister of Health and Social Services to be responsible for the approval of research projects involving incompetent minors or adults in virtue of Article 21 of the Civil Code of Quebec. Although investigator(s) must still notify the IRB of the starting date of the protocol and the date the study is completed. The IRB reserves the right to examine your study data, including

[redacted]

July 23, 1999
Date

Chairperson
Institutional Review Board

cc: Ms. Alison Burch, MCH Research Institute

L'HÔPITAL DE MONTRÉAL POUR ENFANTS • THE MONTREAL CHILDREN'S HOSPITAL
2300 rue Tupper, Montréal (Québec) H3H 1P3 Tél.: (514) 934-4400

D.2 Projet de recherche PCTSIB/SOT

Centre universitaire de santé McGill
McGill University Health Centre

THE INSTITUTIONAL REVIEW BOARD

The Research Ethics Boards (REBs) of the McGill University Health Centre are registered REBs working under the published guidelines of the Tri-Council Policy Statement, the "Plan d'action ministériel en éthique de la recherche et en intégrité scientifique" (Ministère de la Santé et des Services sociaux, Gouvernement du Québec), and in compliance with standards set forth in the (US) Code of Federal Regulations governing human subjects research, and act in conformity with Good Clinical Practice: Consolidated Guideline (GCP E6).

A Montreal Children's Hospital Committee consisting of:

Jane McDonald, M.D., Chairperson	Microbiology
Kathleen Glass, DCL, Co-chairperson	Ethicist/Lawyer
Michael Shevell, M.D.	Neurology
Saleem Razack, M.D.	PICU
Saleem Al-Tamimen	Pediatrics
Laurel Kimoff, M.D.	Pediatrics
Janet Rennick, Ph.D.	Nursing
Anne Usher, R.N.	Community
Sharon Vance	Community
Robert Barnes, M.D.	Endocrinology
Andrée Prendergast, R.N.	Nonaffiliated
Colombe Blais	Pharmacy

reviewed on November 27th, 2000 the research project entitled:

Comparaison de la performance aux tests d'équilibre Balance Master et Pediatric Clinical Test of Sensory Interaction for Balance

submitted by: Ms. Isabelle Gagnon

and consider it to be within acceptable limits of clinical investigation solely from the point of view of medical ethics. The following conditions apply to the ethical approval of the above-named study:

1. Receipt of scientific approval by the McGill University/Montreal Children's Hospital Research Institute.
2. Final approval of the IRB, i.e. the dated and signed IRB stamp on the French and English versions of the consent form will confirm scientific approval from the Research Institute.
3. If applicable, the contractual agreement must be signed by the appropriate authorities before the study can proceed.
4. The study is approved for a period of one year from the date shown below.
5. Prior to the end of the one-year period, the investigator(s) must advise the Institutional Review Board of the number and status of participants enroled in the study. We wish to be advised promptly of any significant adverse outcomes.
6. The investigator(s) must inform the Institutional Review Board should any changes be made to the study protocol and/or consent form.
7. Investigator(s) must notify the IRB of the starting date of the protocol and the date the study is completed. The IRB reserves the right to examine your study data, including signed consent forms.

[redacted]

Dec 12/00
Date

Chairperson
Institutional Review Board

cc: Ms. Alison Burch, MCH Research Institute

L'HÔPITAL DE MONTRÉAL POUR ENFANTS • THE MONTREAL CHILDREN'S HOSPITAL
2300, rue Tupper, Montréal (Québec) H3H 1P3, Tél.: (514) 934-4400

ANNEXE E

Abrégés présentés lors de congrès scientifiques

E.1

Mild traumatic brain injury affects children's confidence in their physical activity performance

Swaine B, Gagnon I, Forget R.

7th annual conference of the Euroacademia Multidisciplinaria Neurotrumatologica
Newcastle-upon-Tyne, UK, 26-29 Juin 2002
Acta Neurochirurgica, 2002; 144(7): A35

References:

1. Swaine B, Yang H, Pless I, Platt R (1999) Proceedings of the Third World Congress on Brain Injury. Quebec City, Quebec, Canada, p 230
2. Salcido R, Costich J (1992) Brain Injury 6: 293–298

Mild Traumatic Brain Injury Affects Children's Confidence in their Physical Activity Performance

B. Swaine[1,2], I. Gagnon[1,2,3], R. Forget[1,2]

[1] Centre de recherche interdisciplinaire en réadaptation du Montréal métropolitain, (CRIR), Quebec, Canada

[2] École de réadaptation Université de Montréal, Quebec, Canada

[3] Montreal Children's Hospital-McGill University Health Center, Quebec, Canada

Introduction: Discharge management protocols similar to those for returning athletes to sports have been proposed for returning children to sports and leisure activities following a traumatic brain injury (TBI). Little is known, however, about how a TBI might affect children's physical activity (PA) level, competence and self efficacy in physical activity upon their return to such activities.

The purpose of this study was to document the PA level, competence and self-efficacy in PA among children who had sustained a mild TBI (mTBI) before and after injury and to compare these data to those of a non-injured control group matched for age, sex and PA level.

Methods: Thirty-two children aged 8 to 16 years (mean: 12.2 ± 2,9) were recruited in each group. Children with mTBI had been admitted to hospital for an observation period of several hours or an overnight stay, had a mean GCS score of 14.8, were considered normal on a standard neurological assessment at hospital discharge, and were all allowed to resume regular physical activity 4 weeks after the injury. Children with mTBI were assessed one day post injury to document pre-injury status, and at 12 weeks post-TBI. Non-injured children underwent the same assessments at a corresponding time interval. The following assessment tools were used: the Physical Activity Questionnaire (level of PA) [1], the Athletic Competence subscale of the Self-Perception Profile for Children or Adolescents (competence in PA) [2] and a Self-Efficacy scale adapted for children with TBI (confidence in PA).

Results: Two-way ANOVAs (group, time) with repeated measures on the factor time revealed that mTBI children performed significantly worse than those non-injured only on the self-efficacy scale at 12 weeks post-injury. Paired t tests performed within each group revealed a decrease ($p < .001$) in self-efficacy for the mTBI, while the non-injured group increased ($p = .018$) over the 12 week interval. The difference between the initial and 12 week self efficacy level for the mTBI group, was significantly correlated with the number of post-concussion symptoms at 4 and 12 weeks, but not with age, admission GCS or other PA variables.

Conclusions: In conclusion, although mTBI children had returned to their pre-injury level of PA and had maintained their competence trait, they did not feel as confident in their ability to perform their activities at 12 weeks post-injury as compared to how they felt before their injury.

References:

1. Crocker PRE, Bailey DA, Faulkner RA, Kowalsky K, McGrath R (1997) Med Sci Sports Exercise 29: 1344–1349
2. Harter S (1982) Child Develop 53: 87–97

The NHS Information Authority Head Injury Groupings Programme

E. Taylor-Whilde

Clinical Researcher NHSIA, London, UK

The project has developed Head Injury groupings anchored in evidence of effective practice, both Healthcare Resource Groups (HRGs) and Health Benefit Groups (HBGs). These have been designed to be used by both commissioners and providers.

The NHSIA's "Healthcare Framework" provides the philosophical rationale underpinning the Groupings. It requires information to be collected around patient needs, interventions and outcomes, and is summed up in the questions "who are we treating?"; "what are we doing with and for them?"; and "what's the effect?"

This Healthcare Framework (HCF)maps healthcare needs and interventions for people at risk of or with head injury. It identifies standard Health benefit Groups (HBGS) for use by the NHS in its analysis of healthcare needs.

The HBGs are groups of people with similar healthcare needs who, given similar interventions, may be expected to have a similar range of outcomes. They are related where available to Healthcare Resource Groups (HRGs), which are groups of intervention episodes expected to consume similar amounts of healthcare resource and are clinically homogeneous.

The component matrices are intended to be a description of head injury existing in a population and the potential options for intervention. They are designed to relate to a population of patients rather than be used in the context of clinical guidelines applying to an individual. However where clinical guidelines have been developed nationally these have been used.

The analytical strategy has been simple: to collect data from sources in the three categories (patient needs, interventions and outcomes). Some pilot work has been undertaken, identifying sources of data, and testing the concepts of Healthcare Frameworks, Health Benefit Groups and Healthcare Resource Groups. Over the past 12 months the Healthcare Framework has been refined and validated by a Clinical Working Group made up of experts from a broad range of Royal College and Professional Bodies representatives as well as being internally peer reviewed by Clinicians working within the NHS Information Authority. The Groupings work is now at a stage where further detailed piloting will be required by volunteers within the NHS.

Commissioners and Providers can use the matrices:

- as a means of identifying the current services delivered for groups of people
- as a means of displaying possible option changes in services
- as a structure for recording the desired pattern of service delivery to be commissioned, and then to monitor the actual delivery of service.

Improving Head Injury Outcome Prediction Using Serum S-100B Level: Are Time-Adjusted Measurements More Accurate?

W. J. Townend[1], C. Dibble[1], K. Abid[2], M. A. Pani[3], D. W. Yates[1]

[1] Emergency Department, Hope University Hospital, Salford, UK

[2] Medical School, Cambridge University, UK

[3] Department of Internal Medicine, University Hospital, Frankfurt am Main, Germany

Introduction: The incidence and extent of disability that may follow apparently minor brain injury are now known to be higher than

E.2

Balance findings after a mild head injury in children

Gagnon I, Forget R, Swaine B, Friedman D
3rd World congress of Neurorehabilitation
Venise, Italie, 2-6 avril 2002
Neurorehabilitation and Neural Repair. 2002; 16: 22-3

Forty five patients with mild to intermediate arm impairment due to a single cortical ischemic stroke underwent a rehabilitation program in a virtual environment in order to apply the "augmented feed-back." Subjects were forced to perform goal-directed skills in numerous virtual scenarios, emulating the correct arm trajectory prerecorded by a physical therapist. During the execution of the task, patients could track on a wall screen their arm trajectory correcting the deviations from the right prerecorded movement. The program consisted of 20 sessions, lasting 1 hour, for 5 days a week.

To evaluate the learning of new motor abilities rather than spontaneous recovery, we selected only patients with a minimum interval of 10 months from the stroke.

The autonomy of daily living activities and the degree of motor impairment were assessed with the functional independence measure scale (FIM) and the Fugl-Meyer upper limb score, respectively.

Moreover, we analyzed the velocity and the morphological characteristics of the end-effector trajectory (patient's hand) in a sequence of specific motor tasks (mainly reaching movements) executed in the virtual environment at the beginning and at the end of the treatment.

Clinical scores improved in response to the therapy: Fugl-Meyer upper limb score and FIM scale improved by 13% and by 7%, respectively. After the treatment, the velocity of end-effector increased 23 %, and it was significantly correlated to the Fugl-Meyer UE score (Spearman's ρ). Likewise, the morphological aspect of the hand trajectories changed from scattered and curved to coherent and straight-line. These data suggested the potential application of the artificially "augmented feedback" in motor rehabilitation.

F22. Postural Control and Attention

I. Speight, A. Reichl, F. Edelhäuser, and H. Masur*
*Department of Neurology, Edith Stein Klinik, Bad Bergzabern; *Center for Clinical Neuropsychology, Würzburg, Germany*

Previous research has shown that sensorimotor processing essential to postural control requires attentional resources. Either by injury or age these attentional requirements associated with maintaining stability are increased to compensate for deterioration within the sensory system. Dual-task paradigms have been used to examine the attentional demands and their allocation during competing postural and secondary cognitive tasks.

The purpose of this study was to determine the effects of impaired attentional capacity on postural stability in a dual-task situation.

Sixty-two subjects were tested: 15 young adults, 10 healthy older adults, and 37 older stroke patients of the Department of Neurology at Edith Stein Klinik. Exclusion criteria were major sensory or balance impairments as well as cognitive deterioration, aphasia, or neglect.

Subjects were asked to maintain steady stance during a no-task or a dual-task condition (fast forward digit counting task). Postural stability (amplitude, anteroposterior, and lateral sway) was measured using the center of pressure (COP) displacement of a dual-plate static force platform. Stroke patients also performed tests of alertness and selective attention.

In the no-task condition, the stroke patients, as expected, swayed significantly more than either of the 2 other groups. The addition of a concurrent cognitive task significantly increased the amplitude and ipsilateral direction of sway in the patient group but had no effect on the young or older healthy adults. Further analysis revealed that significant COP-displacements only occurred in the attention-impaired subgroup of the stroke patients. Results from this study show that impaired attentional capacity in stroke patients affects their postural stability during performance of a secondary cognitive task, while stroke patients with overall attentional ability perform like healthy older adults. Implications for neurological rehabilitation are discussed

F23. Balance Findings after a Mild Head Injury in Children

I. Gagnon[1,2,3], R. Forget[1,2], B. Swaine[1,2], and D. Friedman[3]
[1] CRIR Montreal Rehab Institute, [2]Rehab School, Université de Montréal, [3] Montreal Children's Hospital McGill University Health Center, Montreal, Canada

Controversy remains as to the existence of motor difficulties among children following a mild head injury (HI), especially in the area of balance. The purpose of this study was to compare the balance performance of children who sustained a mild HI with that of noninjured children matched for age, sex, and level of premorbid physical activity. Thirty-two children aged 8 to 16 years (mean: 11.9, *SD*: 2.9) were recruited in each group. Children with HI had been admitted to hospital for an observation period of several hours or an overnight stay and had a mean GCS score of 14.8. All HI children were considered normal on a standard neurological assessment at hospital discharge. Assessments of balance were conducted at 1 and 4 weeks post-HI and at a corresponding interval for noninjured children. The following clinical standardized tools were used to assess different aspects of balance: the balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), the Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB), and the Postural Stress Test (PST). Two-way ANOVAs (group, time) with repeated measures on the factor time revealed that HI children performed significantly worse ($P = 0.002$) than those noninjured only on the balance subtest of the BOTMP, and this at both testing intervals. In fact, on average, HI children performed 2.5 and 1.3 years below aged-matched norms at 1 and 4 weeks respectively, while those noninjured performed at 0.3 years above test norms. These results suggest that, among the tests investigated, only the BOTMP appears to be a useful clinical tool to detect differences in balance between HI and noninjured children. BOTMP scores for HI children improved over the testing intervals but never reached the level of performance of those noninjured. Although no group effect was found, a significant time effect over the 4 weeks was found for children in both groups on the PCTSIB (foam and dome condition) and on the PST, indicating a possible learning effect for these tests. Although considered to have no observable neurological problems at hospital discharge, children demonstrated initial static balance deficits in conditions of restricted base of support without visual input. These problems appear to improve over time but persist until the 4th week post injury. These results lend support to the use of activity restrictions during the initial recovery period, particularly for those requiring subtle balance skills. The exact duration of balance problems, as well as their impact on physical activities remains to be determined in order to develop more specific recommendations regarding balance in children and returning to activities after a mild HI.

F24. Functional Reach: Experimental vs. Clinical Measure of Balance in the Elderly

E. Jonsson, M. Henriksson, and H. Hirschfeld
Motor Control and Physical Therapy Research Laboratory, Department of Physical Therapy, Karolinska Institutet, Stockholm, Sweden

Introduction: Functional Reach (FR) is a common clinical balance test developed by Duncan et al. (1990). FR measures the reach distance at shoulder level between the length of the arm and maximal forward reach in a standing position without altering the base of support. FR is also used as an item in Berg's Balance Scale. Previous reports suggest that FR is a more functional measure of a subject's margin of stability than a forward leaning task about the ankle. One way to explore the stability limits is to investigate the location and path of the ground reaction force vector on the base of support (center of pressure, CoP) during task performance.

Objective: The aim of the study was to investigate changes in body angles and CoP displacement and to correlate them to the clinical FR measure result.

Methods: Twenty-seven healthy elderly subjects (mean age 71.3 years) recruited from elderly organizations in the vicinity of Huddinge participated. Subjects were tested by means of whole body kinematics (ELITE systems) and ground reaction forces (AMTI) from both feet parallel with clinical yardstick measure when performing FR.

Results: The mean value for clinical reach distance was 29 cm (range 18–38 cm). The mean trunk angle of forward bending relative to the vertical axis was 32 degrees, while mean ankle extension was 6 degrees. A low correlation was found between CoP displacement and reach distance ($r = 0.40$). However, a moderate correlation between reach distance and trunk angle ($r = 0.68$) was found. CoP displaced forward (66.3 % mean) on the base of support (stability limits) disregarding reach distance and body movement.

Conclusions: The fact that our results show a low correlation between CoP displacement and reach distance questions whether FR is a functional measure of a subject's stability margins and seems not to favor a forward leaning task.

E.3

Transient increase in response time after a mild head injury in children

Gagnon I, Forget R, Swaine B, Friedman D.
79th Annual Meeting of the American Congress of Rehabilitation Medicine
Philadelphia, USA, 2-6 octobre 2002
Archives of Physical Medicine and Rehabilitation 2002; 83: 1481

Cette présentation a reçu le 1er prix de présentation orale lors de ce congrès

Group 2: Traumatic Brain Injury Treatment Methodology and Efficacy

Article 6

Nonrandomized Studies of Rehabilitation for Traumatic Brain Injury: Can They Determine Effectiveness? Janet M. Powell, PhD (Univ Washington Schl Med, Seattle, WA), Nancy R. Temkin, PhD, Joan E. Machamer, MA, Sureyya S. Dikmen, PhD.

Disclosure: None declared.

Objective: To examine the feasibility of investigating rehabilitation effectiveness for traumatic brain injury (TBI) with a nonrandomized design. **Design:** Observational cohort with confounder control by regression methodology. **Setting:** Level I trauma center. **Participants:** Consecutive series of 365 individuals with TBI discharged to inpatient rehabilitation or home (78% follow-up). **Interventions:** Not applicable. **Main Outcome Measures:** Glasgow Outcome Scale (GOS), Sickness Impact Profile (SIP), Burden Inventory, and Perceived Quality of Life (PQOL). Predictors of interest included discharge to comprehensive inpatient rehabilitation or home and length of inpatient rehabilitation stay. **Results:** Discharge to rehabilitation was associated with poorer functioning on the GOS (*P*=.03) and SIP (*P*=.57), an increased Burden Inventory (*P*=.14), and an improved PQOL (*P*=.20). Similar results were found for longer lengths of inpatient rehabilitation. **Conclusions:** The results appear to be due to confounding rather than to rehabilitation. The study design could not control for confounding resulting from unmeasured or difficult to measure aspects of clinical decisions for discharge placement and rehabilitation length. Furthermore, typical severity indices were inadequate to control for injury severity and recovery. Matching designs investigating TBI rehabilitation are also at risk for inadequate confounder control. **Key Words:** Brain injuries; Rehabilitation; Research design.

Article 7

Botulinum Toxin Type A as an Adjutant Treatment for Severe Posttraumatic and Postanoxic Spasticity: A Randomized, Double-Blind, Within-Subject Placebo-Controlled Administration. Nancy Childs, MD (Texas NeuroRehab Center, Austin TX), Walt N. Mercer, PhD, Steve Stansilav, PharmD.

Disclosure: None declared.

Objective: To evaluate the efficacy of botulinum toxin type A (Botox) in severe spasticity. **Design:** Single-center, double-blind, placebo-controlled. **Setting:** A specialized, inpatient, brain injury program in a free-standing rehabilitation hospital. **Patients:** 9 men, 7 women (Rancho Los Amigos levels II–III). Injury type included trauma (81.3%) and anoxia (18.7%). **Interventions:** Treatments included Botox and serial casting for 16 pairs of limbs. Targeted muscles included the gastrocnemii and posterior tibialis. **Main Outcome Measures:** Costs of casting, Botox, occurrence, and treatment of skin breakdown. **Results:** Although fewer casts were required during serial casting, using the number of casts and incidence of skin breakdown, the difference between Botox and the placebo medication was not statistically significant. **Conclusions:** While clinical impression suggests that Botox is efficacious, our results suggest there is no significant difference between Botox and placebo when given with serial casting. **Key Words:** Botulinum toxin type A; Brain injuries; Persistent vegetative state; Rehabilitation.

Article 8

Writing an Informed Consent for Research to Be Understood by Individuals With Traumatic Brain Injury. Cynthia L. Harrison-Felix, MS (Craig Hosp Res Dept, Englewood, CO).

Disclosure: None declared.

Objective: To develop an informed consent for research document for individuals with traumatic brain injury (TBI). **Design:** Ethical principles, local institutional review board (IRB) criteria, and readability formulas were used to design an informed consent document. **Setting:** A federally designated Traumatic Brain Injury Model Systems center. **Participants:** Adults with TBI receiving inpatient rehabilitation and participating in research. **Interventions:** Not applicable. **Main Outcome Measures:** Sentence length, word difficulty, formatting, readability statistics. **Results:** The previous informed consent document contained long paragraphs with an average of 2.4 sentences per paragraph, 24.3 words per sentence, and 4.8 characters per word. The Flesch Reading Ease score was 45.6 and the Flesch-Kincaid Grade Level was 12. The new informed consent document has a question-answer format with bulleted statements and contains an average of 1.1 sentences per paragraph, 10.4 words per sentence, and 4.2 characters per word. The Flesch Reading Ease score is 74.1 and the Flesch-Kincaid Grade Level is 5.5. **Conclusions:** By using some simple ethical principles, IRB guidelines, and readability formulas, an informed consent for research document can be made easier to understand for individuals with TBI. It is also recommended to ask individuals providing consent to explain what they are being asked to do to assure that they understand the research. **Key Words:** Brain injuries; Informed consent; Rehabilitation.

Article 9

Systematic Bias in Traumatic Brain Injury Outcome Studies Due to Loss to Follow-Up. John D. Corrigan, PhD (Craig Hosp Res Dept, Englewood, CO), Cynthia Harrison-Felix, MS, Jennifer Bogner, PhD, Marcel Dijkers, PhD, Melissa Sendroy Terrill, BA, Gale Whiteneck, PhD.

Disclosure: None declared.

Objective: To identify potential sources of selection bias created by subjects lost to follow-up in studies of traumatic brain injury (TBI). **Design:** Demographic, premorbid, injury-related, and hospitalization characteristics were compared between subjects lost and found for 1- and 2-year postinjury follow-ups, using bivariate tests and logistic regression analysis. **Setting:** 3 prospective, longitudinal datasets. **Participants:** Adolescents and adults hospitalized with a diagnosis of TBI. **Interventions:** Not applicable. **Main Outcome Measures:** Subjects were considered lost when no information was collected from the person with TBI, or only limited information could be obtained from a proxy. **Results:** At year-1 follow-up, 58.0% to 58.6% of subjects were found; 39.7% to 42.0% of subjects were found at both years 1 and 2. Regression variables most frequently associated with loss to follow-up were cause of injury, blood alcohol level, motor function, hospital payer source, and race and ethnicity. **Conclusions:** TBI follow-up studies may experience selective attrition of subjects who are socio-economically disadvantaged, have a history of substance abuse, and have violent injury etiologies. These phenomena are mitigated for those with more severe motor deficits. Loss to follow-up may be inherent to this population; however, the high rate and its selective nature are problematic for outcome studies. **Key Words:** Brain injuries; Follow-up studies; Rehabilitation.

Article 10

Virtual Environment Training Improves Functional Movement in Patients With Acquired Brain Injury. Maureen K. Holden, PhD, PT (MIT, Cambridge, MA), Annegret Dettwiler, EdD, PT, Thomas Dyar, MA, Daniel J. Keating, PhD, George Niemann, PhD, Emilio Bizzi, MD.

Disclosure: Supported by Bancroft NeuroHealth, The Charles A. Dana Foundation, and the National Institute of Child Health and Human Development, National Institutes of Health (grant no., HD40959).

Objectives: To assess the feasibility of training a functional movement (pouring from a cup) using a virtual environment in subjects with acquired brain injuries and to evaluate motor learning and generalization to the real world following training. **Design:** Single-subject ABABA design. **Setting:** Nonprofit postacute brain injury facility. **Patients:** 8 patients with primarily hemiparetic deficit (5 right, 3 left) caused by acquired brain injury (mean age, 27.3±8.8y; mean duration postinjury, 9.5±9.5y; range, 2.5–19y). **Interventions:** 16 (n=8) or 32 (n=4) sessions of virtual environment training for involved upper extremity. **Main Outcome Measures:** Upper-extremity motor performance was tested in *Real World* using: the Fugl-Meyer Test of Motor Recovery (FM), Wolf Motor Test (WMT), and 3-dimensional kinematics during a pouring test. **Results:** Pre- and posttraining comparison used a paired *t* test. Both Fugl-Meyer total per extremity (*P*=.034) and WMT (*P*=.009) improved significantly. Fugl-Meyer motor subtest showed a trend (*P*=.068). Preliminary analysis of the 3-dimensional trajectory data suggest straighter, smoother pour movements, reduced hand and trunk excursions, movement times, and number of velocity peaks following training. **Conclusions:** The improvements demonstrated by our chronic acquired brain injury subjects following treatment suggest that virtual environment training may be a useful new method in neurorehabilitation. **Key Words:** Brain injuries; Rehabilitation; User-computer interface.

Group 3: Traumatic Brain Injury Quality of Life

Article 11

Women With TBI: A Population at Risk Before Injury? Tamara Bushnik, PhD (Northern California Traumatic Brain Injury Model System of Care, Santa Clara Med Ctr, San Jose, CA).

Disclosure: Supported by the National Institute on Disability and Rehabilitation Research, Office of Special Education and Rehabilitative Services, US Dept of Education (grant no. H133A970018).

Objective: To compare premorbid characteristics of women with traumatic brain injury (TBI) with population norms and men with TBI. **Design:** Longitudinal data collection. **Setting:** 17 Traumatic Brain Injury Model Systems (TBIMS). **Participants:** 331 women and 1052 men in the TBIMS National Database. **Interventions:** Not applicable. **Main Outcome Measures:** Premorbid demographic and psychosocial characteristics. **Results:** The national average for high school completion for ages 18 to 24 years is 85%, compared with 67% (women) and 56% (men) in this sample. National high school dropout rates for ages 16 to 24 years are 12%, compared with 27% (women) and 36% (men) in this sample. 35% of US women aged 25 to 34 years are married, compared with 28% of the women in this sample. 9.8% of US adults are divorced; the divorce rate in this sample was 12% (women) and 13% (men). Heavy drinking rates are estimated in 10% of the population, compared with 31% (women) and 59% (men) in this sample. 6.4% of adults report using illicit drugs, compared with 21% (women) and 36% (men) in this sample. Lifetime incarceration rates for US women are 1.1%; 2.7% of the sample women reported incarceration pre-TBI. **Conclusions:** Women with TBI had substantially worse demographic and psychosocial characteristics, compared with US population norms, although not to the degree that men with TBI did. **Key Words:** Brain injuries; Rehabilitation.

Article 12

Transient Increase in Response Time After a Mild Head Injury in Children. Isabelle Gagnon, PT, MSc (CRIR Inst Readaptation de Montreal; Ecole de Readaptation Univ Montreal; Montreal Children's Hosp-McGill Univ Health Ctr, Montreal, Que, Canada), Robert Forget, PT, PhD, Bonnie Swaine, PT, PhD, Deborah Friedman, PT, BSc.

Disclosure: None declared.

Objective: To compare the response time of children after a mild head injury with that of noninjured children matched for age, sex, and premorbid level of physical activity. **Design:** Cohort study. **Setting:** Pediatric trauma center. **Participants:** 37 children aged 7 to 16 years (mean, 12.2±2.8y) were recruited in each group. Children with mild head injury had a mean Glasgow Coma Scale score of 14.8, and were considered normal on a neurologic assessment at hospital discharge. Noninjured children were friends of those with mild head injury. **Intervention:** Assessments of response time were conducted at 1, 4, and 12 weeks after mild head injury and at corresponding time intervals for controls. **Main Outcome Measures:** Response speed subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) and results on an apparatus developed for this study to measure reaction time, movement time, and return to target time for both upper and lower extremities, for simple, choice, and reversed choice response time paradigms. **Results:** Children with mild head injury demonstrated lower performance than those noninjured (*P*=.004) on the BOTMP only 1 week postinjury. They also demonstrated slower return to target times at 1 week postinjury (*P*=.026) for the reversed choice response time paradigm for the lower extremities only. Conclusion: Children with a mild head injury demonstrated response time deficits 1 week postinjury that subsequently improve over time. **Key Words:** Brain injuries; Rehabilitation.

Article 13

Perceived Stress in Women With Physical Disabilities. Rosemary B. Hughes, PhD (Baylor Coll Med, Houston, TX), Heather B. Taylor, PhD, Susan Robinson-Whelen, PhD, Margaret A. Nosek, PhD.

Disclosure: None declared.

Objective: To examine the extent to which social support, current abuse, pain, and social isolation contribute to perceived stress among women with disabilities beyond demographic and disability-related factors. **Design:** Correlational design using retrospective data. **Participants:** 415 women with physical disabilities. **Setting:** Outpatient clinics. **Interventions:** Not applicable. **Main Outcome Measure:** Perceived Stress Scale. **Results:** In a multiple regression analysis, the correlates hypothesized as more malleable (social support, social isolation, pain, current abuse) contributed significant variation over and above demographic and disability blocks. Social support was inversely related to perceived stress while current abuse and pain correlated positively to perceived stress. These variables predicted stress over and above all of the other variables considered less malleable. 2 demographic variables (age, household income) and 2 disability variables (mobility, need for personal assistance) contributed significantly to perceived stress. **Conclusion:** Women with physical disabilities may be at risk for greater stress if they lack social support, experience high levels of pain, and/or experience abuse. Perceived stress appears to be greater for women who are younger, have less income, have less mobility, and have greater need for personal assistance. **Key Words:** Rehabilitation; Stress; Women.

Article 14

The Association Between Functional Limitations and Reduced Life Participation. Margaret G. Stineman, MD (Univ Pennsylvania, Philadelphia, PA), Richard N. Ross, MS, Greg Maislin, MS, MA.

Disclosure: None declared.

Objective: To explore how limitations in physical, mental, and social functioning reduce participation in life. **Design:** A multistage sample with weighted data to obtain unbiased parameter estimates. The effect of various types of functional limitation on frequent bed days was estimated through logistic regression after controlling for age, gender, low family income, and less than a high school education. The variable frequent bed days was used to approximate restriction in life participation. **Setting:** The noninstitutionalized population. **Participants:** 108,053 respondents to the 1994 and 1995 National Health Interview Survey. **Interventions:** Not applicable. **Main Outcome Measures:** Reduced participation approximated as spending 30 days or more in bed over the last year. **Results:** People with severe limitations in physical function were 33.2 times more likely (95% CI, 23.8–46.1) to experience frequent doctor visits than those without limitations. Those with limitations in psychologic and social function had odds ratios of 2.1 (95% CI, 1.9–2.3) and 1.9 (95% CI, 1.6–2.2), respectively. **Conclusion:** While severe physical limitations are most highly associated with bed days, social and psychologic functioning were also independent predictors. This highlights the need for physicians to address multiple domains of functioning when attempting to empower people with disabilities in ways that enhance life participation. **Key Word:** Rehabilitation.

Article 15

The Mayo Portland Adaptability Inventory as an Outcome Measure in Pediatric Acquired Brain Injury Rehabilitation. Peter Rumney, MD, FRCPC (Bloorview MacMillan Children's Ctr, Toronto, Ont, Canada), Nancy Thomas-Stonell, BSc, DSP-SLP(C)CCC, Bruce Oddson, PhD.

Disclosure: None declared.

Objective: To determine whether the Mayo Portland Adaptability Inventory (MPAI) is a viable outcome measure in pediatric acquired brain injury rehabilitation. **Design:** Review of a 900-client clinical database in which scores were entered prospectively. **Setting:** An acquired brain injury acute rehabilitation program. **Participants:** Pediatric patients with moderate to severe acquired brain injury. **Intervention:** MPAI as an outcome tool. **Main Outcome Measures:** MPAI at admission, discharge, and then at 6-month and 1-, 2-, 3-, 4-, and 5-year follow-up. **Results:** The MPAI has been adapted to meet the needs of pediatric acquired brain injury rehabilitotion and is reliable and statistically valid in this setting. Correlation of outcomes with early onset indicators of severity show reliable trends with MPAI scores, but assessment of early computer tomography scan results showed no correlation with outcomes. In addition, the correlation of a younger age with a poorer outcome was confirmed using the MPAI and through clinical observation over long-term evaluation. **Conclusions:** The MPAI is useful in outcome evaluation for pediatric acquired brain injury rehabilitation with some necessary modifications. **Key Words:** Brain injuries; Outcome Measure; Pediatrics; Rehabilitation.

Group 4: Measurement and Outcome

Article 16

Psychometric Properties of the McGill Ingestive Skills Assessment. Heather Lambert, OT(C) (McGill Univ Schl Phys Occup Ther, Montreal, Que), Erika Gisel, PhD, OTR, Sharon Wood-Dauphinee, PhD, PT, Michael Groher, PhD, CCC-SLP, Michael Abrahamowicz, PhD.

Disclosure: Supported by Fonds de la Recherche en Santé du Québec, the National Health Research Program, and Canadian Occupational Therapy Foundation.

Objective: To establish the psychometric properties of the McGill Ingestive Skills Assessment (MISA) for elderly individuals with neurogenic dysphagia. **Design:** Psychometric testing, masked comparison. **Setting:** Public long-term care and nursing facilities. **Patients:** Validity data were obtained on a referred sample of 102 participants. Of these, 85 were assessed by 2 independent evaluators during the same meal and 74 were assessed by the same evaluator during 2 meals. **Interventions:** Not applicable. **Main Outcome Measures:** An evaluator blinded to MISA results performed chart reviews and administered the Modified Mini-Mental State Examination (Modified MMSE). Nursing staff blinded to MISA results completed the Global Deterioration Scale and FIM™ instrument. **Results:** Intraclass correlation coefficients were used to determine reliability. Interrater reliability was .86 for the total score (range, .67–.95 on 5 scales; 95% CI, .79–.91). Intrarater reliability was .88 (range, .63–.88; 95% CI, .82–.92). Validity was evaluated by regression analyses of MISA scores with FIM, Global Deterioration Scale, and Modified MMSE scores. A priori hypotheses based on documented relationships between feeding skills, mental status, and activities of daily living were confirmed. **Conclusions:** The MISA has adequate validity and reliability for research and for patient assessment. **Key Words:** Dysphagia; Rehabilitation.

Article 17

Conceptualization and Psychometric Evaluation of the Participation Measure for Postacute Care. Barbara Gandek, MS (Health Assessment Lab, Boston, MA), Samuel J. Sinclair, MEd, John E. Ware Jr, PhD.

Disclosure: None declared.

Objective: To evaluate the Participation Measure for Postacute Care (PM-PAC), a participation measure based on the *International Classification of Functioning, Disability and Health*. **Design:** Cross-sectional. **Setting:** New England rehabilitation centers. **Participants:** 395 patients (mean age, 60; 59% female) with neurologic (n=155), non-central nervous system trauma (n=24), orthopedic (n=105), or other medical (n=111) diagnoses. **Interventions:** Not applicable. **Main Outcome Measures:** The PM-PAC was constructed to measure limitations in 9 domains (mobility, role functioning, employment, education, leisure and civic life, social relationships, information exchange, home life, economic life) from the patient's perspective. Higher scores reflect fewer reported limitations. The PM-PAC also includes questions measuring the frequency of activities, contacts, and other categoric items. **Results:** Internal consistency reliability (Cronbach α) ranged from .73 to .92 (median=.81) for the 9 scales. As hypothesized, scale scores generally reflected clinical severity (eg, orthopedic patients with a Rankin Scale of no/slight disability had higher scores [fewer limitations] than moderate and severe patients [$P<.05$]). Days per week spent away from home and employment status were significantly ($P<.0001$, hypothesized direction in parentheses) related to mobility (+), role functioning (+), and leisure and civic life (+) scores. However, time away from home was not related to the communication or social relationships scales. **Conclusion:** The PM-PAC is a promising tool for measuring participation in noninstitutional rehabilitation settings. **Key Words:** Patient participation; Psychometrics; Rehabilitation.

Article 18

Comparison of Management of Delayed-Onset Muscle Soreness. Hyun Seok, MD (Dept Rehabil Med, Coll Med, Soonchunhyang Univ, Chunan, Korea), Ki-Hyun Kim, MD, Jae-Ho Moon, MD, Jun Rae Noh, MD.

Disclosure: None declared.

Objective: To investigate the efficacy of physical therapy or analgesics in the management of delayed-onset muscle soreness. **Design:** Double-blind, randomized trial. **Setting:** Hospital laboratory. **Participants:** 52 healthy university students (48 men, 4 women) with no musculoskeletal disease participated. **Intervention:** Subjects randomly allocated to 1 of 5 treatment groups: heat therapy, cold therapy, aspirin (3g), acetaminophen (1950mg), and placebo (n=10, for each group). Subjects were asked to extend their nondominant knee with concentric methods and to try to hold the knee with eccentric contraction at 30° angular velocity. They performed 10 repetitions and then rested for 30 seconds. This process was repeated until exhaustion. **Main Outcome Measures:** Visual analog scale (VAS), McGill Pain Questionnaire (MPQ), and Pain Rating Score (PRS). The MPQ was taken on days 1 and 5; other measurements were taken on each day of experiment. **Results:** The VAS and PRS showed changes over time, but no significant difference in peak scores and relief time between groups ($P>.05$). The MPQ showed incremental change over time, but no significant difference between groups ($P>.05$). **Conclusion:** There was no beneficial effect from cold or heat therapy or from commonly prescribed medications in the management of delayed-onset muscle soreness. **Key Words:** Acetaminophen; Aspirin; Cryotherapy; Heat; Rehabilitation.

Article 19

Magnetic Field Therapy for Symptomatic Diabetic Neuropathy. A Randomized Double-Blind, Placebo-Controlled Trial. Michael I. Weintraub, MD (New York Med Coll, Valhalla, NY), Gil L Wolfe, MD, Steven P. Colege, PhD, for the Diabetic Neuropathy Magnetic Research Group.

Disclosure: None declared.

Objective: To determine if constant wearing of multipolar, static magnetic foot insoles (450G) can reduce neuropathic pain and improve quality of life (QOL) scores in symptomatic diabetic peripheral neuropathy (DPN). **Design:** Randomized, placebo-control study. **Setting:** 48 centers in 27 states. **Participants:** 375 subjects with stage II to III DPN were randomly assigned to constantly wear magnetized insoles for 4 months, whereas placebo group received similar, unmagnetized device. **Intervention:** Nerve conduction and/or quantified sensory testing were performed serially. **Main Outcome Measures:** Visual analog scale (range, 0–10) scores were tabulated daily for neuropathic pain and QOL issues. Secondary measures included electrodiagnostic changes, role of placebo, and safety issues. **Results:** Statistical reduction in burning ($P<.01$), numbness and tingling ($P<.05$), and exercise-induced foot pain ($P<.01$) during months 3 and 4 was noted in patients with severe symptoms (analysis of covariance, Bonferroni correction, Farrar stratification). There were no adverse events or changes in secondary outcome measures. **Conclusions:** Static magnetic fields can penetrate up to 20mm and appear to target the ectopic firing nociceptors in the epidermis and dermis. Analgesic benefits were achieved over time. **Key Words:** Diabetic neuropathies; Magnetics; Rehabilitation.

E.4

Decreased postural stability following a mild traumatic brain injury in children

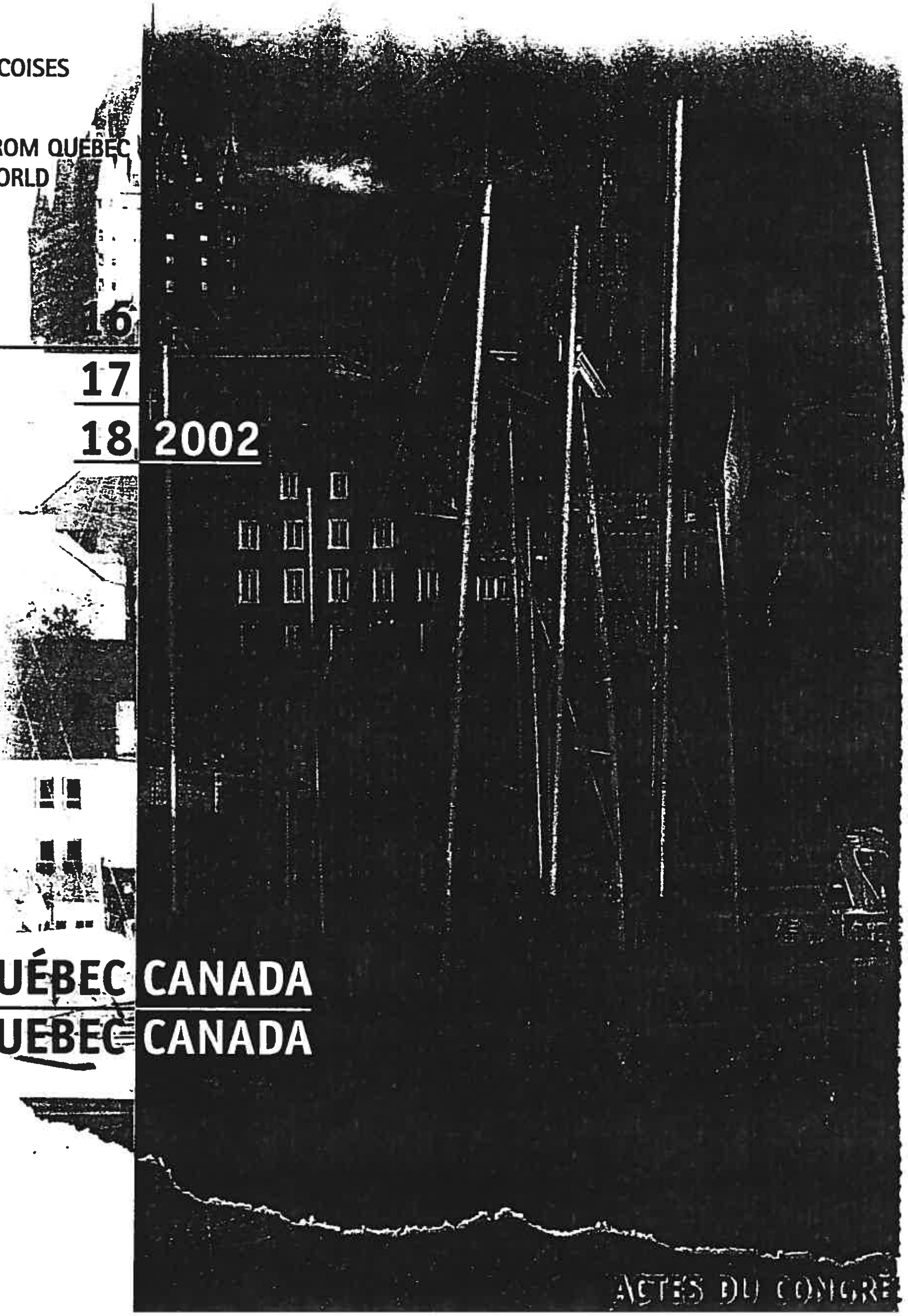
Gagnon I, Swaine B, Forget R, Friedman D.
Congrès International de Réadaptation en Neurotraumatologie
Québec, Canada, 16-18 octobre 2002

Congrès international de réadaptation en traumatologie

International Conference on Post-Trauma Rehabilitation

INNOVATIONS QUÉBÉCOISES
ET INTERNATIONALES

INNOVATIVE IDEAS FROM QUEBEC
AND AROUND THE WORLD



Octobre
October 16
17
18 2002

QUÉBEC CANADA
QUEBEC CANADA

ACTES DU CONGRE

Québec City, July 31, 2002

Subject : Your poster proposition « Decreased postural stability following a mild traumatic brain injury in children »
For the International Conference on Post-Trauma Rehabilitation

Madam, Sir :

We have read with much interest your submission for the poster session and we have the pleasure of informing you that we accept your proposal.

We would like to remind you a few technical points :

- Each poster should be 1 meter X 1 meter.
- Each panel can display two posters.
- Posters will be grouped by themes, for example : TBI, SCI, OI, interventions, research, etc.
- The posters will be displayed in the room where the « pauses-santé » will be taken. On your arrival, you will be shown the place where the presentation will be held.
- There will not be any electrical outlets or special lighting available.
- People participating in all three days of the congress will have to install their poster between 10 a.m. and noon on Wednesday, October 16th and take them down from 10 :30 a.m. Friday, October 18th.
- People presenting posters for a single day will have to install them in the morning and take them down in the evening, before leaving.
- Velcro should be used to hand up posters.

Please note that to participate at the poster session you should first be registered at the congress.

N.B. There will be one table and two chairs available at each information stand.

We thank you for your interest in presenting the results of your research or the technical equipment necessary for rehabilitation in the field of traumatology and we hope that you have a pleasant stay with us.

[redacted]

Gabriel Cabanne, Chair
Scientific Committee

Abrégé présenté au Congrès international de réadaptation en traumatologie. Québec, 16-18 octobre 2002.

Decreased postural stability following a mild traumatic brain injury in children

The existence of balance difficulties in children following a mild traumatic brain injury (mTBI) remains controversial. The purpose of this study was to compare the balance of children who sustained a mTBI with that of non-injured children matched for age, sex and level of pre-morbid physical activity. Thirty seven children aged 7 to 16 yrs (12.2±2.8) were recruited in each group. Children with mTBI had a mean GCS of 14.8 and were considered normal on a neurological assessment at hospital discharge. Non-injured children were friends of those with mTBI. Assessments were conducted at 1, 4 and 12 weeks post-MTBI and at corresponding time intervals for the controls. The following clinical standardized tools were used to assess different aspects of balance: the balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), the Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB) and the Postural Stress Test (PST). MTBI children performed significantly worse than those non-injured on the balance subtest of the BOTMP(p=.001) and on the PST (p=.03). These results suggest that, among the tests investigated, the BOTMP and the PST appear to be useful clinical tools to detect differences in balance between mTBI and non-injured children. A significant time effect over the 12 weeks was found for both groups on some PCTSIB items (p=.05-.001)and on the PST (p=.001), indicating a possible learning effect for these tests. Although considered to have no observable neurological problems at hospital discharge, children demonstrated difficulties in dynamic balance for conditions of restricted base of support and in response to external perturbations. These problems appeared to improve over time, but persisted until the 12th week post injury. As such, they should be taken into consideration when planning a return to physical activities, particularly to those requiring subtle balance skills.

E.5
Gagnon I, Swaine B, Forget R, Friedman D.
Return to physical activities after a mild traumatic brain injury in children
9th Research Colloquium on Rehabilitation, McGill University
Montreal, 25 avril 2003

Cette présentation a reçu le 1er prix de présentation orale lors de ce colloque

REPAR
Réseau provincial
de recherche
en adaptation-
réadaptation

McGill
School of Physical and
Occupational Therapy

CRIR
Centre de recherche
interdisciplinaire
en réadaptation
du Montréal métropolitain

9th Research Colloquium in Rehabilitation

9ième Colloque sur la recherche en réadaptation

PROGRAM and ABSTRACTS

PROGRAMME et ABRÉGÉS

April 25, 2003
McIntyre Medical Building
3655 Promenade Sir-William-Osler
Montreal, P.Q.

25 avril 2003
Pavillon McIntyre
3655, Promenade Sir-William-Osler
Montréal, P.Q.

RETURN TO PHYSICAL ACTIVITIES AFTER A MILD HEAD INJURY IN CHILDREN. Isabelle Gagnon (Robert Forget, Bonnie Swaine) Sciences Biomédicales, Université de Montréal, Québec.

Objective: Little is known about how a TBI might affect children's return to physical activities (PA). The purpose of this study was to document the PA level, competence and self-efficacy in PA among children who had sustained a mild TBI (mTBI) before and after injury and to compare these data to those of a non-injured control group matched for age, sex and PA level. **Methods:** 32 children (12.2yrs ± 2,9yrs) were recruited in each group. Children with mTBI had been admitted to hospital for an observation period of several hours or an overnight stay, had a mean GCS score of 14.8, were considered normal on a standard neurological assessment at hospital discharge, and were all allowed to resume regular physical activity 4 weeks after the injury. Children with mTBI were assessed 1 day post injury to document pre-injury status, and at 12 weeks post-mTBI. Non-injured children underwent the same assessments at a corresponding time interval. The following assessment tools were used: the Physical Activity Questionnaire (level of PA), the Athletic Competence subscale of the Self-Perception Profile for Children or Adolescents (competence in PA) and a Self-Efficacy scale adapted for children with TBI (confidence in PA). **Results:** MTBI children performed significantly worse than those non-injured only on the self-efficacy scale at 12 weeks post-injury. The difference between the initial and 12 week self efficacy level for the mTBI group, was significantly correlated with the number of post-concussion symptoms at 4 and 12 weeks, but not with age, admission GCS or other PA variables. **Conclusions**: In conclusion, although mTBI children had returned to their pre-injury level of PA and had maintained their competence trait, they did not feel as confident in their ability to perform their activities at 12 weeks post-injury as compared to how they felt before their injury.

E.6

The Sensory Organization Test and the Pediatric Clinical test of Sensory Interaction for Balance: Do they really measure the same concepts?

Gagnon I, Swaine B, Forget R.
14th World Congress of Physical Therapy
Barcelone, Espagne, Juin 2003

14th International
WCPT Congress
Barcelona, Spain 2003

WCPT Secretariat

46-48 Grosvenor Gardens
London SW1W 0EB
England UK

tel. 44 (0)20 7881 9234
fax 44 (0)20 7881 9239

info@wcpt.org

14thcongress@wcpt.org

c/o Isabelle Gagnon
Montreal Children's Hospital
McGill University Health Center
Physical Therapy Department
2300 Tupper, Montreal
Quebec H3H 1P3
Canada

19 December 2002

Dear Colleague,

WCPT 14TH INTERNATIONAL CONGRESS

Thank you for submitting your abstract ref 1563 entitled:

THE SENSORY ORGANIZATION TEST AND THE PEDIATRIC CLINICAL TEST OF SENSORY INTERACTION FOR BALANCE: DO THEY MEASURE THE SAME CONCEPT IN HEALTHY CHILDREN?

for presentation at the 14th International Congress of WCPT.

We have pleasure in informing you that your abstract has been accepted as a Research Report Poster.

Before we can place your abstract in the final programme we must receive the following information. Please send this to us as soon as possible, but absolutely no later than **15 FEBRUARY 2003** :-

1. **Confirmation of your intention to present**

Please email isc@wcpt.org, quoting your Abstract Ref No, advising whether or not you intend to present this abstract (don't forget to include items (2) & (3) listed below)

2. **Completed audio-visual requirements form**

This form is attached to this letter.
Please check we haven't made any errors in your abstract title, contact details etc. **Please do not make any amendments on the form, details of any corrections should be included in your email**

3. **Speakers biography**

This should be no more than 100 words, and should contain any information you would like to be included when the Chair of your session introduces you. (Please remember to quote your Abstract Ref No, Name and Abstract Title)

4. **Registration form & fee**

You must register for the Congress if you intend to present your abstract. You can register online at www.wcpt.org/congress by completing the online registration form, or downloading a copy of the registration form and posting or faxing it to the Congress office. **When completing the registration form, please enter your Abstract Ref No after your name.** If you've already registered without including the Ref. No, don't worry, this is not essential.

RR-PO-1563 **Wednesday 11:30, Palau de Congressos, Exhibition Hall [Display No. 694]**

THE SENSORY ORGANIZATION TEST AND THE PEDIATRIC CLINICAL TEST OF SENSORY INTERACTION FOR BALANCE: DO THEY MEASURE THE SAME CONCEPT IN HEALTHY CHILDREN? Gagnon, I, Swaine, B, Forget, R; School of Rehabilitation, Faculty of Medicine, University of Montreal, Montreal, Canada.

PURPOSE: As balance is a pre-requisite to many activities, its evaluation is a core component of the pediatric rehabilitation specialist's assessment. Both the Sensory Organization Test (SOT) of the Neurocom Smart Balance Master™ and the Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB), created as an inexpensive clinical alternative to the former, have been developed to quantify the ability to maintain balance in the presence of sensory conflicts and both have been used with children. The purpose of this study was to compare the performance of healthy children on these two evaluations of standing balance. RELEVANCE: It is essential for physical therapists to know whether the PCTSIB can in fact replace the SOT in the pediatric clinical setting. Therefore the relationship between the two measures needs to be established. SUBJECTS: Sixteen healthy children aged 5 to 16 years (9.8? SD=3.5 yrs) participated in this exploratory study. METHODS: Children were assessed at a rehabilitation center during a single 30 minute session, with the PCTSIB always performed first in order to decrease the experimenter bias when administering the the clinical tool. For the SOT, computer controled movements of the standing platform and of the visual background are used to produce sensory perturbations and six different sensory testing conditions were conducted. For the PCTSIB, a foam and a dome are used to perturb proprioceptive and visual inputs respectively, in six sensory testing conditions. The PCTSIB was conducted in tandem and unipodal standing. ANALYSIS: Spearman rank order correlation coefficients were calculated to compare the performances on the PCTSIB to those obtained on the SOT. Coefficients were also calculated to examine the relationship between age and test performances. RESULTS: Only 3 conditions of the SOT were significantly related to the corresponding PCTSIB conditions: the eyes closed-stable surface conditions with both tandem (R2=0.501)and unilateral stance (R2=0.534), and the sway vision-stable surface condition with the unilateral stance position (R2=0.580). The lack of comparability between the two tests in terms of the nature of the support surfaces and of the visual conflict imposed on the children could explain part of the apparent lack of relation. On the other hand, all SOT conditions, four of six PCTSIB unilateral stance conditions but no tandem conditions, were significantly related to age (R2=0.516 - 0.810). CONCLUSION: Although the two tests are associated with age, they do not measure the same sensory organization abilitiesb. As such, they each provide different and complementary information about children's balance.

ANNEXE F

Lettres des éditeurs

ANNEXE G

Déclaration des coauteurs

Déclaration des coauteurs

À qui de droit :

Par la présente, nous les soussignés, donnons la permission de microfilmer le contenu de la présente thèse.

[redacted]

Robert Forget, Ph.D.

[redacted]

Bonnie Swaine, Ph.D

[redacted]

Debbie Friedman, B.Sc.

20 juin 2003