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ORIGINAL REPORT

MOTOR PROFICIENCY IN CHILDREN WITH MILD TRAUMATIC BRAIN INJURY COMPARED WITH A CONTROL GROUP

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Objective: **To assess motor proficiency and movement disorders in children with mild traumatic brain injury compared with an uninjured control group. Inclusion criteria were based on the definitions issued by the American Congress of Rehabilitation Medicine.**

Subjects: **A group of 27 children with mild traumatic brain injury (age range 4–17 years) and a control group of 79 healthy children.**

Methods: **Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) was administered. This is a standardized comprehensive test of gross- and fine-motor function that produces standard scores for children in this age group. It is divided into 4 gross-motor tasks, 3 fine-motor tasks, 1 combined task, and a test of hand and foot dominance. Tremor was also evaluated.**

Results: **The mean standard scores for both groups were within the normal range. For balance, the mild traumatic brain injury group had a significantly poorer performance than controls ($p=0.03$). Tremor was significantly more frequent in the mild traumatic brain injury group ($p=0.004$), and mixed-handedness was significantly over-represented in the mild traumatic brain injury group ($p=0.02$).**

Conclusion: **In this study, children with mild traumatic brain injury did not differ from the norm in terms of fine- or gross-motor proficiency compared with a control group of uninjured children, but a difference in balance skill ($p=0.03$), mixed-handedness ($p=0.02$) and tremor ($p=0.004$) was detected, to the injured children's detriment.**

Key words: motor function; mild TBI; children; control study.

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INTRODUCTION

Head injuries are common; one-third of all newborns world wide will experience a head injury before the age of 16 years and between 80–95% of the injuries are mild (1). In a recent World Health Organization (WHO) study, the mean annual incidence of mild traumatic brain injury (MTBI) at all ages is estimated to be at least 600 per 100,000 inhabitants (2). In a recently published study from Sweden, the annual incidence of MTBI in children (0–17 years) was found to be 468/100,000 (3), which is in agreement with, and comparable to, a Swedish adult population (16–65 years of age) (4).

However, definitions of MTBI vary considerably (5), and this makes it difficult to compare the severity and outcome for this group (6).

Several studies highlight the fact that post-traumatic complaints or post-concussion syndrome (PCS) exist after MTBI and, in some cases, persist for years (2, 6, 7). To date, there are no national guidelines for follow-up after MTBI that include motor function. In Sweden MTBI is regarded as a relatively harmless injury with complete recovery within a couple of weeks (6, 8–10).

Movement disorders after MTBI are usually described in the literature as mild and transient, and severe movement disorders are rare (6, 7, 10, 11). The term "movement disorder" is used to encompass tremors, hypokinetic syndromes and "extra-pyramidal" symptoms. Koller and co-workers (8) found post-traumatic movement disorders in 10% of patients after mild or moderate head injury, the majority of these patients had transient mild tremor, and persistent movement disorders were only rarely detected. No disabling transient low-amplitude postural/intention tremor was found in this group (8). However, Kuhtz-Buschbeck (12) reported that hand motor skills improve less than gait within 5 months after injury. Functional motor function and control are affected 1–2 years after TBI (12), whereas reaction time and movement duration are prolonged. Co-ordination deficits are also frequent (10).

Fine-motor skills are often included in neuropsychology tests, and several studies have been published in this area (2, 13). Only a few studies of gross- as well as fine-motor proficiency post-trauma for MTBI in children have been published (5, 6, 10, 14, 15).

Another complication after severe and moderate head injury is reduced dynamic balance, but this has been only sparsely studied after MTBI (15, 16). According to Rosenblum et al. (17), postural control/balance is defined as the ability to maintain the centre of body mass or a body part over a stable or moving base of support. Gagnon et al. (15) studied a group of injured children and a control group, and found that children with MTBI scored significantly worse than controls in the balance subtest.

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Aim

The aim of this study was to assess general motor proficiency and movement disorders in a group of children over 4 years of age, 3–6 months after a MTBI, and compare their performance with an uninjured control group using the Bruininks-Oseretskys Test of Motor Proficiency.

PATIENTS AND METHODS

Series

The MTBI group consisted of children, age range 0–17 years, registered in a Brain Injury Register (BIR) at Boras Hospital in two different 6-month periods (in 1999 and 2000).

Inclusion criteria were: all children aged 0–17 years fulfilling the criteria for MTBI according to the American Congress of Rehabilitation Medicine (ACRM). MTBI is considered present if any of the following criteria are fulfilled: focal neurological deficit(s) that may not be transient; but where the severity of the injury does not exceed the following: any period of loss of consciousness (LOC) of 30 min or less; any loss of memory for events immediately before or after the accident lasting less than 24 h, or a Glasgow Coma scale (GCS) score of 13–15, 30 min after the injury (18).

Children living in provinces outside the County of South Alvsborg, and children with injuries more severe than MTBI, were excluded.

The study comprised 192 children, 54 of whom agreed to evaluation. Of these, 11 did not attend for evaluation. A total of 43 children were evaluated (a further one was excluded because of myelomeningocele). They were all offered a post-concussion examination (PCE) 3–6 months after injury. The PCE included a motor skills examination, the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) test for children older than 4 years. Of the remaining 42 children, 27 were older than 4 years of age and were eligible for this study.

Control group

A total of 294 children aged 0–17 years, from a school situated in Boras were asked by their parents to participate as a control group. Inclusion criteria were: healthy children with no known concussion or brain injury. Originally 99 children agreed to participate as controls, but 6 were excluded because of a previous concussion episode, thus 93 remained. Of these, 88 children attended the evaluation, 79 of whom were older than 4 years of age and were included in this study.

The study was approved by the ethics committee at Sahlgrenska University Hospital, Gothenburg, Sweden.

Measurements

The complete battery of the English version of the BOTMP (19) was used for the examination. This test is a standardized comprehensive battery of gross- and fine-motor measurements that produces standard scores for children in the age range 4–14 years. The BOTMP consists of 3 composites, and the reliability of these parts is tested using the coefficient alpha; gross-motor function ($r=0.77$), fine-motor function ($r=0.88$) and general-motor function ($r=0.89$). The test is divided into 8 sub-tests: 4 gross-motor tasks, 3 fine-motor tasks, and 1 combined task, comprising 46 separate items and a test for hand and foot dominance. The sub-test standard score has a mean of 15 (standard deviation (SD) 5). Standard scores are interpreted as "below average performance" in groups with scores between 6 and 11, and as "low performance" for scores of less than 6. The composites are expressed as normalized standard scores with means of 50 (SD 10). Hand preference and foot dominance are recorded from one catching and one kicking item using a tennis ball. During the test, any changes in hand or foot preference are noted. Administration of the complete battery took between 45 and 60 min (19).

Any visible hand tremor during the activities was noted.

Mild traumatic brain injury group

The children in the MTBI group ($n=27$) were all examined at the local habilitation centre. All examinations were performed by the same physiotherapist and the same child neurologist.

Control group

The children in the control group ($n=79$) were examined in the same manner and by the same physiotherapist as the children with MTBI, but the examinations were carried out at their school during school hours.

Statistics

All statistical analyses were carried out using the SPSS®. Descriptive methods were used for the mean, median, age and gender. As the samples were small, non-parametric statistics were used for comparing the groups (Mann-Whitney U test and Pearson's χ^2 test). Statistical significance was set at $p \leq 0.05$. For comparisons between groups, a logistic regression model was used (Fisher's exact test), and for variances Levene's test for equality of variances was used.

RESULTS

This study is based on 27 children with MTBI, age range 4–17 years, mean age 8.6 years (SD 2.6, standard error (SE) ± 0.5), and a control group of 79 children in the same age range, mean age 8.7 years (SD 2.4, SE ± 0.3).

The MTBI group comprised 16 (59%) boys and 11 (41%) girls, and the control group comprised 41 (52%) boys and 38 (48%) girls. The groups were not initially matched by age and gender, although there were no significant differences between the groups (Table I) according to age and gender.

Bruininks-Oseretsky Test of Motor Proficiency

The mean standard score results for the BOTMP in both groups, were all within the range of normal performance (15 ± 5 points).

A significant difference between the groups (MTBI and controls) could be seen only in capacity for balance ($p=0.03$) and a tendency towards a difference in fine-motor dexterity ($p=0.07$). Complete results for the BOTMP are given in Table II.

The mean standard scores for each sub-test were within the range for normal performance. A significant difference between the groups ($p \leq 0.05$) was revealed only for balance ($p=0.03$).

Tremor

Tremor was more common in the MTBI group; 8 children in the MTBI group ($n=27$) had visible tremor in their hands during fine-motor activities, compared with 6 ($n=79$) children in the control group ($p=0.004$).

Table I. *Number and age distribution of all children examined by the Bruininks-Oseretsky Test of Motor Proficiency*

Group	Number	Mean age	SD	SE	CI
MTBI	27	8.6	2.6	0.5	–1.18 to 0.98
Controls	79	8.7	2.4	0.3	–1.2 to 1.0

MTBI: mild traumatic brain injury; SD: standard deviation; SE: standard error; CI: confidence interval.

Table II. *Bruininks-Oseretsky Test of Motor Proficiency results: the 4 subtests of gross-motor function and upper-limb co-ordination and the 3 subtests of fine-motor function*

	MTBI group $n=27$			Control group $n=79$			
	Mean (SD)	Median	Range	Mean (SD)	Median	Range	p-value
Gross-motor function							
Running speed and agility[a]	9.1 (4.9)	9	1–17	9.9 (3.9)	11	1–17	Ns
Balance	15.4 (4.4)	15	1–20	17.4 (4.7)	18	1–26	0.03
Bilateral co-ordination	17 (5.1)	17	1–19	18.4 (3.7)	19	1–19	Ns
Strength	16.3 (6.1)	17	1–28	17.1 (4.8)	17	1–21	Ns
Upper-limb co-ordination	16.2 (4)	17	1–17	17 (4.5)	17	1–24	Ns
Fine-motor function							
Response speed	16.9 (6.2)	16	1–22	19.1 (5.6)	19	1–24	Ns
Visio-motor control	17.2 (5)	18	1–22	18.3 (4.5)	19	1–25	Ns
Dexterity	11.9 (7)	10	1–25	13.7 (4.7)	14	1–23	Ns

[a]$n=78$.
Standard score [15±5 points].
Ns: not significant; SD: standard deviation; MTBI: mild traumatic brain injury.

Handedness

Several children in the MTBI group used both hands (mixed-handed) in fine-motor activities, instead of having a left- or right-hand dominance (Table III).

There was a positive relationship between upper-limb speed and dexterity and hand dominance. It appears that right-handed children perform tasks more quickly than left or mixed-handed children (SE ± 5.2, $p=0.05$).

According to the above results a linear regression analysis (Fisher's exact test) was conducted between the groups' (dominators), handedness (right-handed and mixed-handed) balance, fine-motor control, dexterity and tremor (numerators). The results indicate that children with MTBI run an increased risk of developing tremor in their hands (relative risk (RR) = 0.068, SE ± 0.90, $p=0.03$) and developing balance problems (RR = 1.11, SE ± 0.06, $p=0.07$). The analysis also indicated an increased risk of being afflicted with MTBI if the child was mixed-handed compared with a dominant right-handedness (RR = 9.95, SE ± 0.82, $p=0.005$). Age or gender had no impact on the results.

Subgroups

Sub-groups were detected in both the MTBI group and the control group. The sub-groups consisted of the children who performed less than the standard norm in one or several subtests of the BOTMP. The sub-groups comprised 19 (70%) children from the MTBI group, 11 boys and 8 girls, mean age 9.0 years (SD 2.6, SE ± 0.6) and 45 (59%) controls, 21 boys and 24 girls, mean age 9.2 years (SD 2.4, SE ± 0.4). There were no significant differences in performance between MTBI and control groups, except for bilateral co-ordination ($p=0.05$) and strength ($p=0.05$) (Levene's test for equality of variances), but the results were still within the standard norms for age and gender (Table IV).

Table III. *Distribution of children with respect to handedness*

BOTMP	MTBI $n=27$	Controls $n=79$	p-value
Hand preference			
Right-handed	17 (63%)	68 (86%)	Ns
Left-handed	1 (4%)	0	Ns
Mixed-handed	9 (33%)	11 (14%)	**0.02**

Statistically significant result are marked in bold.
BOTMP: Bruininks-Oseretsky Test of Motor Proficiency; MTBI: mild traumatic brain injury; Ns: not significant.

DISCUSSION

The design of this study is prospective from a BIR. The children were encouraged by their parents, 3–6 months after the injury, to participate in the project.

Concussion is a common occurrence. The guidelines for follow-up after the injury have been inadequate, and there has been a tendency for both the healthcare system and the general public to play down any consequences. To ensure the reliability of our results, a control group was tested.

Table IV. *Distribution of standard scores for the mild traumatic brain injury (MTBI) and control groups*

	BOTMP		Controls $n=45$		
Subtest	Mean (SD)	SE	Mean (SD)	SE	p-value
Running speed and agility	7.6 (4.9)	1.1	7.7 (3.6)	0.55	0.19
Balance	14.7 (4.6)	1.05	17.4 (4.7)	0.74	0.54
Bilateral coordination	15.9 (5.3)	1.21	16.7 (3.9)	0.57	**0.05**
Strength	15.2 (6.8)	1.57	15.4 (4.2)	0.63	**0.05**
Upper limb coordination	15.6 (4.2)	0.97	15.6 (5.2)	0.78	0.38
Response speed	16.2 (6.6)	1.51	17.5 (5.6)	0.83	0.39
Visio-motor control	16.1 (5.3)	1.23	17.1 (5.1)	0.76	0.73
Fine-motor control and dexterity	9.2 (5.7)	1.30	12.0 (4.7)	0.70	0.79

Statistically significant result are marked in bold.
Standard score [15±5 points].
BOTMP: Bruininks-Oseretsky Test of Motor Proficiency; SE: standard error; SD: standard deviation.

The BOTMP is useful as a test for comparing groups and evaluating differences between them (19, 20, 21). The test battery is easy to administer, giving instructions is straightforward, the items are independent of age and gender, and the children find the test interesting and enjoyable to perform. In our study we used the English version, as no Swedish version is available as yet, and our plan was not to validate it to Swedish conditions. We feel that there are no crucial differences between Swedish and Canadian children in terms of their motor activity and ability. At the time of our study only the first edition of the BOTMP was available (19). In this study we have not collected facts about the children's motor performance pre-injury and cannot, with absolute certainty, state whether their motor behaviour was changed post-injury.

Fine-motor control and balance

In the present study the BOTMP test in 27 children with acquired MTBI and 79 controls indicated that the MTBI group performed less well in sub-tests of fine-motor control and dexterity ($p=0.07$), which agrees with the findings presented by Chaplin and co-workers (5). They evaluated 14 patients 16 months or later after injury using the BOTMP, and reported that upper-limb speed and dexterity were significantly poorer than the other fine-motor sub-tests.

In our study balance was significantly poorer in the MTBI group compared with the control group ($p=0.03$), but it was still in the range of normality. In the literature to date, cognitive problems after MTBI are more frequently discussed than motor problems. However, several research teams have found that balance problems are frequently involved in both mild injuries and more serious TBI (20–24). Gagnon et al. (15, 16) have suggested that a significant number of children sustaining an MTBI present some form of postural instability during the first 3 months after the injury, and the risk of another injury will therefore increase.

Tremor

The results indicated that children with MTBI run an increased risk of developing tremor in their hands (RR = 0.068, SE ± 0.90, $p=0.03$), and the occurrence of tremor in the MTBI group ($p=0.004$) compared with the control group was significant. Hand tremor was not tested specifically, but it was noted in the clinical examination by both the physiotherapist and the child-neurologist independently of each another.

Tremor post-head injury is well-described in the literature, but it is rarely seen after MTBI (6, 11, 14). When it occurs it is often as a non-disabling, low-amplitude, postural and kinetic tremor and might be seen as a post-concussion symptom (11, 24–26). In our study, tremor was observed during fine-motor activities and had no impact on the child's fine-motor function.

Handedness

In the present study 9/27 children (33%) (mean age 7.8 years) in the MTBI group displayed mixed-handedness, compared with 11/79 (14%) (mean age 6.6 years) in the control group ($p=0.02$). A stable hand preference can be expected at approximately 3 years of age (27). The literature describes changes in hand dominance after severe TBI, but this is rarely described after MTBI (28, 29). On the other hand, our analysis indicated an increased risk of having MTBI if the child was mixed-handed compared with a dominant right-handedness (RR = 9.95, SE ± 0.82, $p=0.005$). Age or gender had no impact on the results. In a recent study, Domellöv et al. (28) suggested that left- and/or non-right-handedness is over-represented in children with a history of preterm birth associated with brain insult. The children in this study were all born at term with no previous history of brain injury of any kind.

Subgroups

A statistical analysis was conducted for children performing below norm in any of the BOTMP's sub-tests. A sub-group consisting of 19 children with MTBI (19/43) and 45 controls (45/79) was then detected. Significant differences were found between the injured children and the controls for the sub-tests of bilateral co-ordination and strength ($p=0.05$). The problems with bilateral co-ordination are in agreement with the findings of Kusch-Buschbeck and co-workers from 2003 (12).

Study strengths and weaknesses

This study was initially designed as a prospective follow-up study, as described elsewhere (3). In order to compare motor proficiencies between the groups the BOTMP test was used. The BOTMP is internationally well known and validated and has been used in several studies for the purpose of testing motor proficiency in children with varying diagnoses (5, 19, 21). All the children in the MTBI group were examined between 3 and 6 months' post-injury by the same physiotherapist and the same child neurologist.

The drop-out rate was high, despite several reminders, and only 21% (27 of 130) in the MTBI group attended the follow-up. Although the drop-out rate was high, the patients did not differ from the whole group of children ($n=192$) in terms of severity of injury, loss of consciousness and post-traumatic amnesia (3). We can only speculate about why so few parents with injured children wanted to participate in a follow-up post-injury. It may be that they did not consider it important, or that the children had no obvious or emerging problems or symptoms following trauma and a follow-up survey was therefore not a priority.

Conclusion

The results of this study indicate that children with MTBI do not differ from the norm in terms of fine- or gross-motor proficiency, compared with a control group of uninjured children. However, a difference in balance skill ($p=0.03$), mixed-handedness ($p=0.02$), and tremor ($p=0.004$) was detected, to the injured children's detriment. The number of children included in the study was limited, however. Further studies are desirable in order to develop adequate follow-up routines for this group of patients.

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