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Cognitive functions and symptoms predicting later use of psychiatric services following mild traumatic brain injury in school-age

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ABSTRACT

Objective: To investigate whether neuropsychological test performance or presence of some specific injury symptoms at 1–3 months following pediatric mild traumatic brain injury (mTBI) can help to identify the children at risk for developing post-traumatic psychiatric symptoms.

Methods: Data from 120 children and adolescents aged 7–15 years, treated at Turku University Hospital between 2010 and 2016 due to mTBI, and who had undergone neuropsychological evaluation at 1–3 months following injury, were enrolled from the hospital records. Neuropsychological test performancesand injury symptom reports were retrospectively retrieved from the patient files.

Results: Slow information processing speed ($p = 0.044$), emotion regulation deficit ($p = 0.014$), impulsivity ($p = 0.013$), verbal processing difficulties ($p = 0.042$) and headache ($p = 0.026$) were independent predictors for having later contact in psychiatric care.

Conclusions: Neuropsychological examination containing measure of information processing speed, injury symptom interview, and parental questionnaires on behavioural issues of the child at 1–3 months following mTBI seems to be useful in detecting children with risk for post traumatic psychiatric symptoms. Targeted support and guidance for this group of children and adolescents and their families are recommended to prevent the development of an unfavorable psychosocial outcome.

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Introduction

A high prevalence of psychiatric and neuropsychiatric disorders has been widely reported in patients with traumatic brain injury (TBI) compared to the population in general (1–5). The rate of comorbid neuropsychiatric disorders in children and adolescents with mild TBI (mTBI) has been found to vary from 10% to 100% (4). Even a single mTBI during childhood has been reported to increase the risk for psychopathology development during adolescence (6,7) and the need for psychiatric care later in life (8,9). The number of novel psychiatric disorders (NPD) following mTBI in childhood or adolescence has been reported to vary from 11.5% to 31% (5,10,11). In our earlier retrospective patient register study (12), we found that 24.2% of the children treated in hospital due to mTBI had had a contact in psychiatric care by the end of the follow-up period of seven years. While the high incidence of subsequent psychiatric problems following a pediatric mTBI has been widely recognized, the literature on specific risk factors for an adverse psychosocial outcome, excluding pre-injury psychiatric problems, is still somewhat mixed and scarce (4, 13–16).

Prolonged physical and cognitive injury symptoms have been found to predict reduced health-related quality of life, thereby comprising a major risk factor for the development of mental health problems (17–20). Rates of perceived injury symptoms beyond one month following pediatric mTBI have been reported to vary from 25% to 53% (21), with girls being overrepresented in having prolonged recovery (19,22). It has been suggested that especially with increasing age, the female sex seems to be a risk factor for developing internalizing symptoms following mTBI (23,24). In our recent study, we found a contact to psychiatric care prior to mTBI, female sex, and presence of at least one self- or parent-reported injury symptom at 1–3 months following mTBI to be predictive for having later contact to psychiatric care (12).

Neuropsychological deficits have been found to be related to the occurrence of NPD following pediatric mTBI. Most typically affected cognitive domains include memory functions, information processing speed, and executive functioning (3,5). Neuropsychological test methods along with child and caregiver evaluations of change in behaviour or functioning are typically used instruments in evaluating neuropsychological symptoms following an mTBI (25,26). Pre- as well as postinjury reading capacity, cognitive processing speed, and adaptive functioning, as measured by parental questionnaires on child's behaviour, have been found to predict NPD following mTBI in hospitalized children (5,11,27). However, in a recently published paper including only children treated in emergency

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department (ED), an association between premorbid cognitive functioning and NPD was not found (28).

The aim of this study was to explore if neuropsychological test performance at 1–3 months following an mTBI at the age of 7–15 years, would predict development of post-traumatic psychiatric symptoms presenting as a contact in psychiatric unit within the study period. Furthermore, we wanted to examine if certain post mTBI symptoms, (e.g., fatigue, headache) would be especially predictive for having later contact to psychiatric care, as we have reported earlier that presence of any self- or parent-reported injury-related symptom at 1–3 months following the injury predicts later contact in psychiatric unit (12).

Methods

This study was conducted at the Department of Pediatric Neurology of Turku University Hospital (TUH), Finland. Approval for the study was granted by the Ethics Committee of The Hospital District of Southwest Finland and TUH (136/2018).

Participants

A total of 120 (56.7% male) children and adolescents treated at TUH due to an mTBI during the years 2010–2016, who were 7–15 years of age at the time of injury, had brain CT or MRI examination available, and had undergone neuropsychological examination at 1–3 months following injury were included into the study group. The data were collected retrospectively from the hospital records. Eligibility criteria for mTBI included the lowest Glasgow Coma Score (GCS) of no less than 13/15, loss of consciousness (LOC) of less than 30 minutes, and duration of post-traumatic amnesia of no more than 24 h. Of the total 415 children who met the criteria for an mTBI, 120 (29%) had a neuropsychological examination carried out within 1–3 months from injury. Criteria for a neuropsychological examination and representativeness of included patient sample have been reported in our earlier paper (12).

Data concerning pre- as well as postinjury psychiatric appointments were culled from the TUH patient records as documented by the end of 2019. Of the participants 17 (14.2%) had had preinjury contact in psychiatric care as measured as having a minimum of one preinjury appointment in regional child or adolescent psychiatry units. Following the mTBI 29 (24.2%) of the participants had had a contact in regional psychiatric units. Of the participants, 18 (15%) had had their first appointment in department of psychiatry following the mTBI, with girls being overrepresented (61.1%). The time interval from the injury event until first referral into department of psychiatry varied from 14 days to 91 months (median 15 months). The most common reasons for referral into psychiatric unit were depressive or anxiety symptoms (12). Demographic information and clinical characteristics of the study participants are presented in Table 1.

Methods

Neuropsychological methods

Neuropsychological examinations were carried out by experienced hospital psychologists at TUH at 1–3 months (mean 74 days) following the mTBI, between the years 2010 and 2016. The neuropsychological examination lasted approximately 3 h and was in most cases performed during one outpatient visit. All examinations included a semistructured interview of the patient and his/her caregiver, questionnaires, and neuropsychological tests according to the hospital's protocol for a neuropsychological evaluation in pediatric TBI. The interview included an assessment of novel posttraumatic issues, as well as a perceived aggravation of earlier problems linked to possible developmental issues. Injury symptom assessment included a concise developmental and family history interview especially concerning diagnosed neurodevelopmental disorders. As neuropsychological data was originally gathered within a clinical context, some variation existed in the methods used in individual study participants.

Children's overall neurocognitive ability was assessed using *The Wechsler Intelligence Scale for Children, WISC IV* (29), which is a widely used test in measuring the intellectual ability of 6–16 years old children and adolescents. WISC IV consists of 15 subtests measuring verbal comprehension, perceptual reasoning, working memory, and processing speed. Among the 120 participants, 111 had performed an abbreviated version of WISC IV including similarities, block design, digit span, and coding subtests. The participants' standard scores in these subtests were used as outcome variables.

The Conners Continuous Performance Test's second version, CPT-II (30), is a computer-based test for measuring sustained and selective attention and vigilance. In the test, situation letters appear randomly and alternately in the centre of a computer screen. A participant must react to a stimulus (any letter but X) and inhibit a reaction when the distractor stimulus (letter X) appears. The CPT-II was performed by 75 of the 120 participants. T-scores for subdomains were used as outcome variables.

The Five to Fifteen – questionnaire, 5–15 (31), was used in elucidating the parent's views of the strengths and weaknesses of the child in several behavioural and functional domains and to give a comprehensive overview of the neurocognitive and behavioural status of the child as perceived by the parents. The questionnaire comprises 181 items from eight domains as follows: Motor skills, Executive functions and attention, Perception, Memory, Language, Learning, Social skills, and Emotional/Behavioural problems. Median raw scores for individual subdomains were used as outcome variables. The questionnaire was available for 70 of the 120 participants.

The Behaviour Rating Inventory of Executive Functions, BRIEF (32), is a standardized rating scale specifically developed to assess children's executive function (EF) deficits as displayed in everyday surroundings, seen by parents and teachers. The BRIEF has been widely used in many clinical samples including pediatric TBI (33). In the questionnaire EF difficulties are classified into eight subscales (Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor), and then

Table 1. Demographic and clinical characteristics of the mTBI group (n = 120).

Age at injury	
Mean (SD)	11.9 (2.5)
Range	7–15
Sex	*N* (%)
Male	68 (56.7)
Female	52 (43.3)
Length of hospital stay at injury	
Outpatient visit	29 (24.2)
1 day	53 (44.2)
2 days	16 (13.3)
3–7 days	20 (16.7)
>7 days	2 (1.7)
Symptomatic at 1–3 months following injury	
No	52 (43.3)
Yes	68 (56.7)
Type of symptoms	
Verbal processing deficits	9 (7.5)
Headache	26 (21.7)
Emotion regulation problems	22 (18.3)
Impulsivity	8 (6.7)
Attention and executive function deficits	13 (10.8)
Memory problems	20 (16.7)
Fatigue	32 (26.7)
Mood problems	9 (7.5)
Motor problems	2 (1.7)
Pre-injury contact to child/adolescent psychiatric unit	
No	103 (85.8)
Yes	17 (14.2)
Post injury contact to child/adolescent/adult psychiatric unit	
No	91 (75.8)
Yes	29 (24.2)
First contact to psychiatric unit following injury (NPD)	18 (15.0)

transformed into The General Executive Composite Score (GEC), which in turn can be divided into the Behavioural Regulation Index (BRI) and The Metacognition Index (MI). The Official Finnish translation of the BRIEF was used in this study. Both GEC, BRI, and MI scores were used as outcome variables. Only parental evaluations were included in this study. A filled questionnaire was available for 37 of the 120 participants. The neuropsychological methods used along with descriptive information are reported in Table 2.

Injury symptoms

Information on ongoing injury symptoms was collected using a semistructured clinical interview, carried out by an experienced hospital psychologist. All the study participants and their caregivers were systematically asked about changes in cognition, speech, school performance, peer-relations, irritability, and mood, as well as physical symptoms including headache, dizziness, disturbances in balance, fatigue, and sleep disturbances. The presence of change in behaviour or well-being since the injury in these domains as reported by children or their parents, was used as a dichotomous outcome variable. Injury symptoms are reported in detail in Table 1.

Data analyses

Statistical analyses and descriptive statistics were performed using the SPSS software (version 25.0 IBM Corp., Armonk, NY). The normality of continuous variables was checked using histograms. Binary logistic regression analyses were conducted in predicting the later contact in psychiatric care by using standard scores of WISC IV subdomains, *t*-scores of CPT II subdomains, the BRIEF and 5–15 subscales, and presence of injury symptoms as predictors in multivariable logistic models. Multivariable models were adjusted for preinjury psychiatric contact and sex, according to the findings from our previous study (12). The results were expressed using odds ratios (OR) with 95% confidence intervals (CI). The differences in the domains of the 5–15 questionnaire between children with and without a later psychiatric contact were tested using Mann–Whitney *U* test. The comparisons between participants and dropouts were done separately for every neuropsychological test method and questionnaire used, regarding age, sex, presence of injury symptoms at the time of neuropsychological examination, history of premorbid learning difficulties, history of psychiatric contact, and length of hospital stay at the time of injury with independent samples *t*-test, chi-square test or Fisher exact, as appropriate. Data analyses were completed using all available data (i.e., including all the cases available on each occasion). *P*-values of less than 0.05 were considered statistically significant, and no adjustments for multiple testing were done.

Results

Neuropsychological test performance and later contact to psychiatric care

Of the WISC IV subtests, performance in coding subtest predicted having later contact in psychiatric care in unadjusted analyses (p = 0.044), as well as when adjusted for preinjury psychiatric contact and sex (p = 0.041). The effect was not modified by sex (Sex*WISC IV coding interaction effect p = 0.226). Performance in any other WISC IV subtests was not predictive for usage of psychiatric services. Hit response time domain of the CPT II predicted later contact to psychiatric care when adjusted for preinjury psychiatric contact (p = 0.047), but not in unadjusted analyses or when adjusted for preinjury psychiatric contact and sex. Any other domains of the CPT II test were not predictive for later contact to psychiatric care.

The General Executive Composite score (GEC) for the BRIEF -questionnaire filled in by the parents predicted later psychiatric contact of the child in unadjusted analyses (p = 0.043), but not when adjusted for earlier psychiatric contact and sex. The Behaviour Regulation Index (BRI) predicted later contact to psychiatric care in unadjusted analyses (p = 0.021), as well as when adjusted for preinjury psychiatric contact (p = 0.022), but not after adjustment for sex. Metacognitive Index (MI) was not predictive for later psychiatric contact. The associations of neuropsychological test performance with later contact to psychiatric care are reported in detail in Table 3.

Parents of the children having a contact to psychiatric care following the injury, rated them as having more problems in all the domains of the 5–15 questionnaire, compared to the parents of the children without later contact to psychiatric care. Parental 5–15 evaluations for the children with and without later contact to psychiatric care are presented in detail in Supplemental Table 1.

Table 2. Neuropsychological methods.

Method	N	Mean (SD) or Median [IQR]	Range
WISC IV			
Coding (standard score)	109	9.86 (3.23)	1–17
Digit span (standard score)	111	9.68 (2.93)	3–19
Block design (standard score)	111	9.55 (3.12)	3–15
Similarities (standard score)	109	9.25 (3.02)	1–15
Vocabulary (standard score)	105	9.10 (3.11)	1–17
CPT II (t-scores)	76		
Omissions		46.68 [10.38]	41.44–75.00
Comissions		53.40 (9.33)	31.73–73.42
Hit RT		43.09 [10.09]	26.95–77.72
Hit RT Std error		44.37 [12.86]	31.12–90.00
Variability		47.62 (11.36)	28.22–82.00
Detectability		53.67 (9.43)	24.88–77.14
Perseverations		48.53 [11.17]	42.59–120.91
HIT RT ISI change		48.96 (8.47)	32.31–77.97
HIT RT SE change		46.76 (9.92)	26.93–68.64
HIT SE block change		47.45 [8.20]	30.03–87.34
BRIEF (index)	37		
MI		51.43 (14.98)	30–87
BRI		46.00 [17.00]	35–86
GEC		50.32 (14.24)	30–89
5–15 (median raw-scores)	70		
Motor		0.06 [0.20]	0.00–1.53
EF		0.26 [0.65]	0.00–1.84
Perception		0.00 [0.13]	0.00–1.06
Memory		0.18 [0.55]	0.00–1.73
Language		0.05 [0.25]	0.00–1.11
Learning	67	0.18 [0.61]	0.00–1.71
Social		0.07 [0.19]	0.00–1.52
Emot./behav.		0.11 [0.34]	0.00–1.24

Injury symptoms and later contact to psychiatric care

Child or parent-reported emotion regulation difficulties ($p = 0.014$) and impulsivity ($p = 0.013$) remained as significant predictors for later contact to psychiatric care when adjusted for earlier contact to psychiatric care and sex. Reporting headache as well as verbal processing difficulties at 1–3 months following injury predicted later contact to psychiatric care as unadjusted ($p = 0.018$, $p = 0.033$), and when adjusted for earlier psychiatric contact (p = 0.026, 0,042), but not for sex. A complete list of reported injury symptoms and their associations with later contact to psychiatric care are presented in detail in Table 4.

Dropout analyses

As the neuropsychological examination was originally performed within a clinical context, variation existed among the methods used, thereby leading to a relatively high amount of missing data. Dropout analyses were performed to analyse the representativeness of the sample. Analyses between participants and dropouts were performed separately for every neuropsychological test method and questionnaire used, regarding age, sex, presence of injury symptoms at the time of neuropsychological examination, history of premorbid learning difficulties, history of psychiatric contact, and length of hospital stay at the time of injury. For the 5–15 questionnaire, more children and adolescents in the participant group had premorbid learning difficulties compared to dropouts (p = 0.009). No other significant differences between the groups were found. Dropout analyses are presented in detail in Supplemental Table 2.

Discussion

The aim of this study was to determine if neuropsychological test performance or the presence of some specific injury symptoms at 1–3 months postinjury predicted later contact into psychiatric services within our retrospective cohort. The present study adds to the findings of our previous study, where we found the presence of any prolonged injury symptom and female sex to be predictive factors for later contact to psychiatric care (12).

We found that when adjusted for preinjury psychiatric contact and female sex, information processing speed as measured with performance in coding subtest of the WISC IV was predictive for having later contact in psychiatric care. Furthermore, hit response time in the CPT II predicted later psychiatric contact when adjusted for preinjury psychiatric contact. These findings are in line with e.g., Max et al. (5), who concluded slower cognitive processing speed to be a risk factor for NPD. However, in this study we only found that information processing speed was predictive for having later contact to psychiatric care, whereas emergence of an actual NPD was not studied. Slow information processing speed has been shown to increase general cognitive workload and effort required, thereby easily leading to ongoing strain and development of secondary psychosocial problems (34). As it has been well addressed that disruption in brain connectivity has negative impact on information processing speed (35,36), it is possible that performance in processing speed tasks reflects underlying structural brain pathology. However, to test this hypothesis, the brain imaging findings of the

Table 3. Neuropsychological test performance at 1–3 months following injury and later visits to psychiatric care.

Predictor	n	Mean (SD)	Unadjusted OR (95% CI)	Unadjusted p-value	Adjusted[a] OR (95% CI)	Adjusted[a] p-value	Adjusted[2] OR (95% CI)	Adjusted[2] p-value
Age (N = 120)								
No	91	12.15 (2.59)	1		1		1	
Yes	29	12.79(2.41)	1.11(0.93–1.32)	0.24	1.07(0.88–1.28)	0.54	0.99(0.81–1.21)	0.92
WISC IV								
Coding (N = 109)								
No	81	10.23 (3.13)	1		1		1	
Yes	28	8.79 (3.32)	0.86(0.75–1.00)	0.044*	0.9(0.77–1.05)	0.19	0.83(0.70–1.00)	0.041*
Digit span (N = 111)								
No	83	9.75 (2.85)	1		1		1	
Yes	28	9.50 (3.21)	0.97 (0.84–1.13)	0.70	1.02 (0.86–1.20)	0.84	1.02(0.86–1.21)	0.84
Block design (N = 111)								
No	83	9.81 (3.05)	1		1		1	
Yes	28	8.79 (3.25)	1.02 (−0.32–2.37)	0.14	0.89 (0.77–1.04)	0.14	0.89 (0.76–1.03)	0.12
Vocabulary (N = 105)								
No	79	9.35 (2.80)	1		1		1	
Yes	26	8.31 (3.88)	0.90 (0.77–1.04)	0.14	0.93 (0.79–1.09)	0.36	0.98 (0.83–1.16)	0.83
Similarities (N = 109)								
No	83	9.49 (2.89)	1		1		1	
Yes	26	8.46 (3.31)	0.89 (0.77–1.03)	0.13	0.89 (0.76–1.04)	0.13	0.90 (0.77–1.01)	0.19
BRIEF (N = 37)								
BRI								
No	28	46.14 (9.29)	1		1		1	
Yes	9	57.89 (14.87)	1.09(1.01–1.17)	0.021*	1.09(1.01–1.18)	0.022*	1.08(1.00–1.17)	0.053
MI								
No	28	48.82 (13.99)	1		1		1	
Yes	9	59.56 (15.84)	1.05(1.00–1.11)	0.072	1.04(0.99–1.10)	0.14	1.03(0.97–1.01)	0.29
GEC								
No	28	47.46 (12.56)	1		1		1	
Yes	9	59.22 (16.19)	1.06(1.00–1.12)	0.043*	1.06(0.99–1.12)	0.069	1.05(0.98–1.12)	0.15
CPT II (N = 76)								
Omissions								
No	53	49.56 (8.33)	1		1		1	
Yes	22	50.53 (6.87)	1.02 (0.96–1.08)	0.63	0.99 (0.91–1.07)	0.76	0.99 (0.91–1.08)	0.77
Comissions								
No	53	52.33 (9.57)	1		1		1	
Yes	22	55.84 (8.63)	1.04 (0.99–1.10)	0.14	1 (0.93–1.07)	0.94	1 (0.93–1.08)	0.93
HIT rt								
No	53	43.97 (6.85)	1		1		1	
Yes	23	48.06 (12.95)	1.05 (1–1.11)	0.076	1.08 (1–1.17)	0.047*	1.08 (1–1.16)	0.058
HIT rt SE								
No	53	45.65 (9.68)	1		1		1	
Yes	23	50.27 (13.01)	1.04 (0.99–1.09)	0.99	1.04(0.99–1.09)	0.16	1.05 (0.99–1.11)	0.82
Variability								
No	53	46.51 (10.95)	1		1		1	
Yes	23	50.16 (12.12)	1.03 (0.99–1.07	0.20	1.03 (0.98–1.08)	0.32	1.04 (0.98–1.10)	0.19
Perseveration								
No	53	53.00 (13.26)	1		1		1	
Yes	23	53.94 (11.21)	1.01 (0.97–1.05)	0.76	1 (0.95–1.05)	0.92	1.02 (0.97–1.07	0.51
Detectability								
No	53	53.20 (10.49)	1		1		1	
Yes	23	54.73 (6.40)	1.02 (0.97–1.07)	0.52	1 (0.94–1.07)	0.92	1.02 (0.95–1.1)	0.60
HIT SE block change								
No	53	48.99(8.29)	1		1		1	
Yes	22	48.07 (8.40)	0.99 (0.93–1.05)	0.66	0.98 (0.90–1.07)	0.64	0.98 (0.91–1.07)	0.70
HIT SE ISI change								
No	53	45.41 (9.87)	1		1		1	
Yes	21	50.16 (9.43)	1.05 (1–1.11)	0.067	1.06 (0.99–1.13)	0.12	1.03 (0.97–1.11	0.33
HIT rt ISI change								
No	53	48.27 (7.91)	1		1		1	
Yes	22	50.63 (9.70)	1.03 (0.97–1.10)	0.27	0.99(0.92–1.07)	0.85	0.99 (0.92–1.07)	0.85

OR = odds ratio; binary logistic regression;
CI = confidence interval.
[a]= Adjusted for contact to psychiatric care prior to mTBI[2] = Adjusted for contact to psychiatric care prior to mTBI and sex.
* $p < 0.05$.

participants should be further analysed and compared to their performance in processing speed tasks.

Our finding of self- or parent-reported emotional dysregulation and impulsivity, as well as higher GEC and BRI scores in the parental BRIEF questionnaires being predictive for the child's later contact to psychiatric care can be interpreted as being in line with Max et al. (5,11), who suggested poor adaptive functioning to be a risk factor for developing NPD

Table 4. Injury symptoms at 1–3 months following injury and later contact to psychiatric care.

		Unadjusted		Adjusted[a]		Adjusted[b]	
Type of symptom	N (%)	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Verbal processing deficits							
No	24 (21.6)	1		1		1	
Yes	5 (55.6)	4.53 (1.13–18.20)	0.033*	4.72 (1.06–21.03)	0.042*	4.97 (0.98–25.35)	0.054
Headache							
No	18 (19.1)	1		1		1	
Yes	11 (42.3)	3.10 (1.22–7.87)	0.018*	3.16 (1.15–8.73)	0.026*	2.54 (0.89–7.28)	0.082
Emotion regulation problems							
No	20 (20.4)	1		1		1	
Yes	9 (40.9)	2.70 (1.01–7.21)	0.048*	3.27 (1.12–9.54)	0.030*	4.25 (1.34–13.51)	0.014*
Impulsivity							
No	25 (22.3)	1		1		1	
Yes	4 (50.0)	3.48 (0.81–14.92)	0.093	5.79 (1.29–25.87)	0.022*	7.82 (1.53–39.93)	0.013*
Attention and executive function deficits							
No	24 (22.4)	1		1		1	
Yes	5 (38.5)	2.16 (0.65–7.22)	0.21	2.96 (0.82–10.67)	0.98	2.77 (0.71–10.78)	0.14
Memory problems							
No	22 (22.0)	1		1		1	
Yes	7 (35.0)	1.91 (0.68–5.37)	0.22	1.77 (0.57–5.46)	0.32	1.97 (0.58–6.73)	0.28
Fatique							
No	19 (21.2)	1		1		1	
Yes	10 (31.3)	1.65 (0.67–4.08)	0.28	1.51 (0.56–4.03)	0.41	1.18 (0.41–3.38)	0.76
Motor symptoms							
No	27 (22.9)						
Yes	2 (100.0)		0.057^				
Mood problems							
No	25 (22.5)	1		1		1	
Yes	4 (44.4)	2.75 (0.69–11.03)	0.15	2.64 (0.58–11.96)	0.21	2.37 (0.50–11.31)	0.28

OR = odds ratio; binary logistic regression.
CI = confidence interval.
[a]= Adjusted for contact to psychiatric care prior to mTBI.
[b]= Adjusted for contact to psychiatric care prior to mTBI and sex.
* $p < 0.05$.
^ OR was not available due to zero frequency (no psychiatric contact among patients with motor symptoms).

following an mTBI. Children's behavioural and emotional difficulties have long been known to be a significant source of parental distress (37), thereby easily leading to negative interactions within a family. Preventing the development of such a negative interaction pattern is crucial, as a two-way connection between the family functioning and outcome from child's TBI has been well acknowledged (38). Early information and injury education is shown to effectively prevent prolonged injury symptoms and perceived distress (39). However, addressing and validating the child's and parents' injury-related concerns is equally important as it may enhance their trust in medical professionals, thereby preventing the development of additional distress (40,41). In addition to injury education, online problem-solving interventions for families are shown efficient in preventing long-term and secondary symptoms following pediatric TBI in general. However, the effect of these interventions in cases with solely mild TBI, remains unclear (42,43). Furthermore, Hunt et al. (20) found that participation into a 6-week outpatient rehabilitation program containing low-intensity aerobic and relaxation exercises along with injury education, significantly decreased mood symptoms following a pediatric mTBI.

Our finding of suffering from headaches at 1–3 months following the injury being predictive for later contact to psychiatric care is important, with a substantial number of children suffering from persistent headaches following an mTBI (44–46). Even if headache is not usually a difficult medical problem, it should be taken seriously and considered as one of the risk factors for prolonged recovery and development of psychiatric symptoms following a pediatric mTBI.

The strength of our study is to include all children referred to neuropsychological examination among those treated at TUH due to an mTBI between the time interval of the study, enabling us to get a clear and comprehensive picture of their outcome. However, as it is likely that the children with more severe injuries and symptoms were referred to neuropsychological examination more often compared to their peers with milder injuries, our sample probably includes a somewhat selected group of children. As the likelihood of persisting injury symptoms has been shown to increase with injury severity (22,47), these results cannot be generalized into pediatric mTBIs in general.

Our study has some additional limitations. First, due to the retrospective study design, the amount of missing data was relatively high, as some variation between the participants existed regarding the methods used in the neuropsychological examination. For the 5–15 questionnaire, dropout analyses showed the participants to have more premorbid learning problems, possibly explaining at least some of the differences found between the groups (Supplemental Table 2). As the questionnaire data was gathered in a clinical context, the reasons for dropouts are not known. One possible explanation could be that the parents of the children in the dropout group did not experience their child having any problems in any of the domains of the questionnaire, and therefore did not fill in the questionnaire.

Second, our finding of slow information processing speed predicting later contact to psychiatric care is concluded based on performance in coding subtest of the WISC IV and hit response time in the CPT II. Even if performance in coding subtest was a statistically significant predictor for later contact to psychiatric care, the mean standard scores for both groups classify as average performance (Table 3). However, as hit response time of the CPT II was found to be predictive for later contact to psychiatric care as well, it gives support to our interpretation. Additionally, as a premorbid estimate for information processing speed was not available, it remains unclear whether the performances in processing speed tasks were related to the sustained mTBI or rather reflected the child's preinjury functioning.

Third, the information on injury symptoms was obtained merely based on a semistructured interview, instead of using any standardized questionnaire, which is a golden standard in evaluating mTBI symptoms. However, all patients were interviewed by an experienced hospital psychologist according to the hospital guideline for neuropsychological examination for children with TBI, containing a routine asking of all typical symptoms following a TBI in children and adolescents.

Conclusions

It is of great importance to recognize the children and adolescents most at risk for developing psychiatric symptoms following an mTBI, as even a single mTBI – especially together with a preceding psychiatric disorder – has been shown to increase suicidal risk at least until early adulthood (48). As an implication of our study, we suggest that a neuropsychological examination containing measures of information processing speed and injury symptom report is carried out following even a single mTBI, especially if there are any known risk factors for prolonged recovery. As we found self- or parent-reported emotional regulation difficulties, impulsivity, verbal processing difficulties and prolonged posttraumatic headache to be predictive for later need for psychiatric services, we suggest especially these symptoms being considered as "red flags" requiring special attention and more intense follow-up. Identifying the individuals most at risk for prolonged recovery and development of secondary symptoms following an mTBI allows for targeted guidance and if needed, timely referral into rehabilitation services, thereby preventing adverse outcomes.

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Disclosure statement

The authors report no conflict of interest. The authors alone are responsible for the content and writing of the paper.

As this study was a retrospective patient register study, the informed consent was not obtained from the participants. Therefore, datasets generated during the study process are not available for public sharing.

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