Fatigue, physical activity and participation in adolescents and young adults with acquired brain injury

Markus-Doornbosch, F. van

Author: Markus-Doornbosch F. van
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Chapter 4

Physical activity, fatigue and sleep quality at least 6 months after mild traumatic brain injury in adolescents and young adults: a comparison with orthopedic injury controls

Frederike van Markus-Doornbosch
Els Peeters
Gerard Volker
Stéphanie van der Pas
Thea Vliet Vlieland
Jorit Meesters

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Abstract

Objectives
To compare physical activity (PA), fatigue and sleep quality in adolescents and young adults (AYAs) after mild TBI (mTBI) to persons of similar age after orthopedic injury (OI) on the longer term.

Setting
Follow-up at least 6 months after visiting the emergency department of one of 2 general hospitals.

Participants
Forty-nine patients aged 12-25 years (mean 18.4 years), diagnosed with mTBI and 54 patients aged 12-25 years (mean 15.8 years) with OI.

Design
Cross-sectional electronic survey study.

Main outcome measures
The Activity Questionnaire for Adults and Adolescents with results dichotomized for meeting/not meeting Dutch Health Enhancing PA recommendations (D-HEPA), the Checklist Individual Strength (range 20-140, low-high) measuring fatigue, and the Pittsburgh Sleep Quality Index (range 0-21, high-low) measuring sleep quality were administered.

Results
Patients with mTBI less frequently met D-HEPA recommendations than patients with OI (49% vs. 70%; OR 2.87, 95%CI 1.07, 7.72) and reported more concentration-related fatigue problems (mean 19.1 (SD 8.0), mean 13.9 (SD 7.8), respectively; β 3.98, 95%CI 0.39, 7.56), after adjusting for potential confounders, sex, BMI, age and time since injury. No differences were found in sleep quality.

Conclusions
Identifying symptoms and limitations in activities is important after mTBI so that rehabiliation treatment can be initiated. Whether physical activity or fatigue is the best target for treatment remains to be established.

Key words
brain injuries, orthopedic injuries, fatigue, sleep, physical activity, pediatric, adolescent

Introduction

Traumatic brain injury (TBI) is one of the leading causes of death and disability in adolescents and young adults (AYAs), with an estimated yearly incidence of 2.25-2.96 per 100 for the age group 15-25 years.[1, 2] The majority is classified as mild TBI (mTBI), with symptoms often resolving within 4 weeks. However, a significant minority reports persistent symptoms.[3, 4] These longer-term consequences of mTBI in AYAs are often multiple and complex, affecting physical, emotional, cognitive and/or social functioning.[4]

Among the persistent symptoms after mTBI in AYAs impaired physical activity (PA),[5] fatigue[6-9] and sleep disorders[6, 10-13] are relatively often reported. With the interpretation of their reported rate or severity, it is important to consider that it may be difficult to unravel to what extent the complaints are a result of damage to the brain or the trauma as such. In this respect, comparisons with a control group of AYAs who have had a trauma involving other body regions, such as orthopedic injury, may be more informative than using controls from the general population. In addition, apart from the control group, potential confounders that need to be taken into account are factors associated with the trauma (e.g. time since injury)[7] and factors associated with PA, fatigue and/or sleep quality in general (i.e. sex, age, Body Mass Index).[14, 15]

Regarding physical activity after mTBI, various studies in adults using self-report questionnaires reported lower levels of physical activity as compared to the general population[16] and decreased PA in individuals after TBI without a control group.[17, 18] Research on PA after mTBI in the pediatric population, particularly in AYAs, focus predominantly on “return to play” or influence of exercise on symptoms and not on the the physical activity levels themselves,[19-21] while literature has identified numerous health benefits of physical activity during adolescence[22] as well as a general decline in physical activity during adolescence.[23]

With respect to fatigue after mTBI in AYAs, the literature is conflicting. Previous studies in (mild) TBI and orthopedic controls in children have found both more fatigability in the children with mTBI at 1 week post injury[24] and 2 years post injury[25] or no difference between the mTBI and control group 2 years post injury.[26]

Concerning sleep difficulties after mTBI in AYA populations, sleep disorders were more often reported as compared to orthopedic and/or healthy controls.[11]

The abovementioned studies make it clear that, although it is conceivable that fatigue and sleep problems are interrelated[27, 28] , most studies in mTBI were so far focussing on only one or two of these dimensions.[6, 9, 11, 29] In addition, only few studies used an appropriate control group.[6, 11, 12] Therefore, the aim of the present study was to compare PA levels, fatigue and sleep quality at least 6 months post injury in AYAs who were diagnosed in a hospital with mTBI or OI. We hypothesised that, due to the nature of the trauma, PA levels would be lower and fatigue and sleep quality would be worse in patients with mTBI as compared to patients with OI.

Methods

Study design

This cross-sectional study was executed at the Haaglanden Medical Center Haga Hospital (location Leyweg and Juliana Children's Hospital), both large teaching hospitals in The Hague. The study included AYAs registered with a trauma in one of the above mentioned hospitals.
The study was approved by the Medical Ethics Review Committee of the Leiden University Medical Center (P12.156) and all patients and their parents (when patient was under 18 years of age) provided written informed consent.

Participants

Patients were eligible for the study if they met all of the following criteria: a.) aged 12-25 years at injury; b.) registered with the diagnosis mild brain injury (Glasgow Coma Scale 13-15) or a fracture of the arm, clavicula, or leg; c.) visited the Emergency Department (ED) of one of the two hospitals between March 1, 2012 and March 1, 2013. Patients were not eligible if they: a.) visited the ED for other head injuries or orthopedic injuries more than once in the same year; b.) underwent surgery related to the trauma; c.) had a diagnosis of both mTBI and OI; d.) had pre-injury medical conditions potentially interfering with their current functioning (such as congenital disorders, rheumatic disease, chronic fatigue syndrome, pain syndrome, sleep disorder, epilepsy, psychiatric disorder i.e. autism spectrum disorder, depression, schizophrenia, conversion disorder or attempted suicide); e.) had an intellectual level with an IQ< 70 based on self-report in ED report or based on school level; f.) were non-fluent in the Dutch language (based on ED report or self-report) or lived outside of The Netherlands.
Date of birth, sex, and date of ED visit were extracted from the medical files (all data extracted by the principle investigator, FvM-D). Medical history (reported in categories: congenital disorder, rheumatic disorder, neurologic disorder, chronic fatigue syndrome, psychiatric disorder or other), multiple ED visits in the past year (yes/no) and surgery (yes/no) were extracted from of the medical files. Location of trauma was categorized in street/traffic related, sport/field, or other: home, school or work).
The severity of TBI was determined by means of the Glasgow Coma Scale (GCS) at hospital admission. According to the GCS, the severity of TBI was considered mild if

the GCS was 13–15, moderate if the GCS was 9–12 or severe if the GCS was <9.[30] When GCS was not reported but the patient was fully conscious (ie, walked into the ED, cycled to the hospital) they were included in the mild TBI group.
For the orthopedic injury group, patients with a fracture of the arm, leg or clavicula without brain injury were identified, as done in an earlier study.[25]

Assessments

Assessments included a one-time survey comprising three validated Patient Reported Outcome Measures (PROMs), to be completed by patients at home, either electronically (NetQ, www.netq.nl) or on paper. Those completing the paper version returned the questionnaire in a pre-stamped envelope. The questionnaires were coded to match the medical records and made anonymous. By providing 2 methods for completing the questionnaire the problems of not having a computer or having computer problems was avoided.
All eligible patients and/or their parents were invited by postal mail in September 2013 and, if they agreed to participate, asked to return the signed informed consent and to state whether they preferred a paper or electronic questionnaire. Patients and/or their parents who did not respond were contacted once by postal mail 2 weeks after the first mailing, and once again by telephone after 3 months. Patients received an incentive (€10 voucher) for completing the questionnaire. Patients were able to respond through the end of December 2014.

General and sociodemographic characteristics

Patients were asked to report their current height and weight; from which body mass index: BMI=weight (kg)/height squared (m^2) was calculated. For patients aged 12 to 17 underweight was defined as BMI < 17.0 and overweight (BMI 25.1-30.0) and obesity (BMI above 30.0).[31,32] For patients 18 years and older cut-off points for underweight, overweight and obesity according to international criteria: <18.5, 25 and >30 kg/m^2, respectively, were used.[33] Current age was determined using the moment of questionnaire completion; for non-responders the mean date of completion was used (June 1, 2014).

Physical activity

Physical activity was measured using the Activity Questionnaire for Adults and Adolescents (AQuAA), a 5 category self-assessment of physical activity based on the SQUASH (Short QUestionnaire to ASsess Health enhancing physical activity). The AQuAA has been validated in the Netherlands for children and adults.[34] However, its psychometric properties were found to be moderate to poor.[35] Patients were asked about the frequency (number of days per week), duration (time spent) and intensity (low, moderate, or vigorous) spent on activities in the past 7 days with examples of activities to facilitate questionnaire completion. Each activity has a MET (Metabolic Equivalent of Task) score related to the intensity of the activity, and is reported as mililiter oxygen use per kilogram bodyweight per minute. The METS compendium developed by Ainsworth[36] was used in this study. Activities were furthur categorized, using the METS for each activity, into low, moderate or vigorous activities,[37] with the total amount of PA being expressed as minutes spent on low, moderate and vigorous activities per week. In addition, the achievement of the Dutch Health Enhancing PA recommendations (D-HEPA) (yes/no) was calculated from the data. In The Netherlands a healthy PA level has been established for children and adults: children (4-17 years of age) should be physically active 60 minutes with moderate to vigorous activities (minimum 5 METS), 7 days a week.[37] Adults meet the criterion if they are physically active (minimum 4 METS) for 30 minutes, 5 days a week.[38] Similar guidelines have been developed by the American College of Sports Medicine,[39] and the World Health Organization.[40] To obtain a more clinically comparable position the data was dichotimized into meeting or not-meeting the D-HEPA.

Fatigue

The Checklist Individual Strength (CIS), was used to measure fatigue. It is a 20-item self-report rating scale for assessing fatigue and associated behavior during the last two weeks. Four domains, (1) severity of fatigue (8 items, score range 8 to 56), (2) concentration problems (5 items, score range 5 to 35), (3) reduced motivation (4 items, score range 4 to 28), and (4) reduced physical activity (3 items, score range 3 to 21) are measured. Each item is scored on a seven point Likert scale. The Total Score is calculated by the sum of the 20 items (range 20 to140). Higher scores indicate higher levels of fatigue, higher levels of concentration problems, decreased motivation, and lower levels of physical activity.[41] A score of 40 or higher on the subscale Fatigue indicates severe fatigue.[42]. The CIS has been validated for use in the adult and pediatric Dutch population.[43]

Sleep Quality

To evaluate sleep quality the Pittsburgh Sleep Quality Index (PSQI)[44] was administered. It is a self-rated questionnaire which evaluates sleep quality and disturbances over a 1 month interval. Seven items (subjective sleep quality, sleep latency (the time from lying down for sleep to the start of actual sleep), sleep duration, habitual sleep efficiency (the proportion of actual sleep time spent in bed), sleep disturbances, use of sleep medication and day time dysfunction) are scored on 4 point Likert scales (0-3, low to high), with a total score ranging from 0 to 21. A global score greater than 5 indicates poor sleep quality.[44] The PSQI has been used in pediatric[45] and adult studies.[46]

Statistical analysis

Among participants, injury (mTBI vs OI) and sociodemographic characteristics (sex, age at injury, time since injury, current age, mechanism of injury and BMI) were analyzed descriptively with Fisher's exact test, independent samples *t*- test or Mann-Whitney-U test, where appropriate. Due to the non-normal distribution of the data, the AQuAA scores in minutes per week were calculated as medians and interquartile ranges (IQR, i.e. the 25^{th} – 75^{th} percentile).

Physical activity levels (AQuAA minutes/week and meeting D-HEPA recommendations yes/no), fatigue (CIS), and sleep quality (PSQI) between the patients with mTBI and OI were analyzed by means of unadjusted linear and logistic regression analysis. Multivariable linear regression was performed to determine the relationship between type of injury (independent variable) and physical activity, fatigue symptoms, and sleep quality (dependent variables) while adjusting for sex, BMI, age, and time since injury. Results were reported as beta and 95% confidence intervals. The natural logarithm of the AQuAA data was used to meet the assumption of normality.

Multivariate logistic regression was performed to assess the impact of type of injury (independent variable) on the likelihood of not meeting the D-HEPA, having severe fatigue symptoms or poor sleep quality (dependent variable), while correcting for sex, BMI, age, and time since injury. Results are reported as odds ratios and 95% confidence intervals. For the comparison of characteristics the level of statistical significance was defined as $p < 0.05$. All analyses were performed using SPSS 22 for Windows.[47]

Results

Four hundred and six patients were identified with mTBI and 464 patients with OI. One hundred patients with TBI were excluded: 7 had a GCS under 13, 12 had multiple ED visits in the same year, 18 underwent surgery, 35 had a medical condition, 7 had a low intellectual level, 11 had a language barrier and 10 had no current address. One hundred and forty-three patients were excluded from the OI group: 27 had multiple ED visits in the same year, 87 underwent surgery, 14 had a medical condition, 8 had a language barrier and 7 had no current address. Three hundred and six patients with mTBI and 321 patients with OI were selected from the registries, considered to be eligible for the present study and were approached for participation in the study (Figure 1).

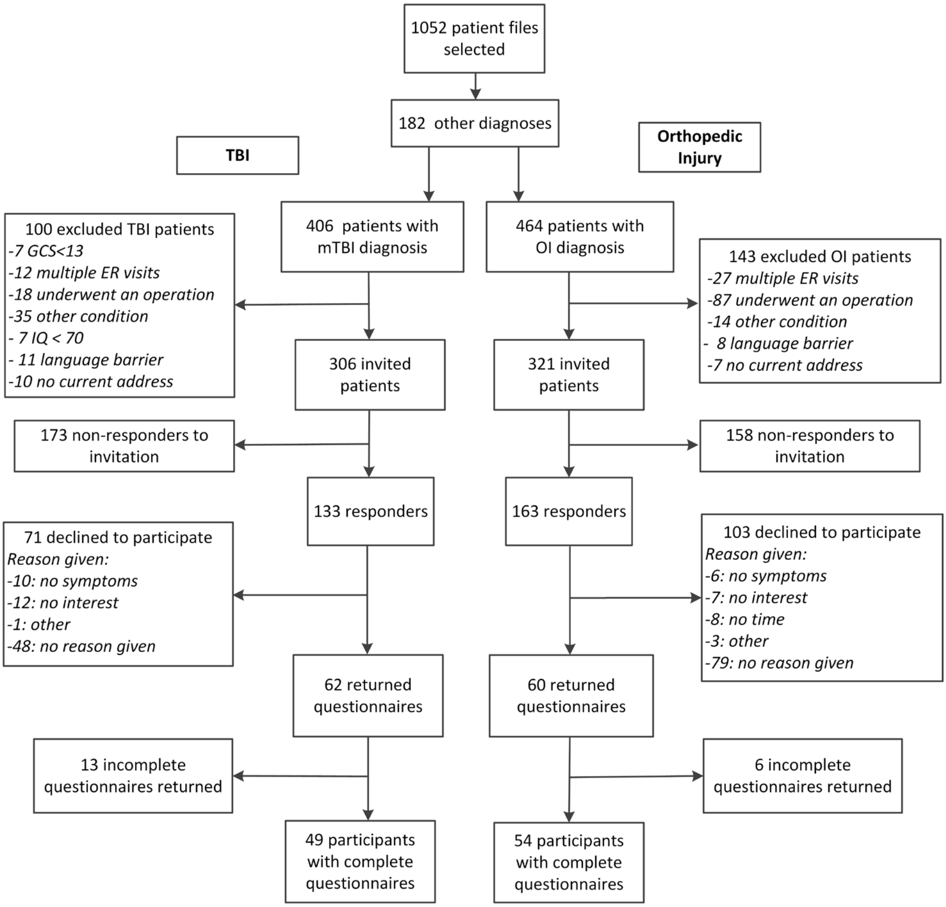

Figure 1. Flowchart of participants adolescents and young adults with mild traumatic brain injury (mTBI) and participants with an orthopedic injury (OI) seen at the Emergency Department.

Regarding the participants, there was no significant difference in sex (p=0.43) or time since injury (p=0.13) between patients with mTBI or OI. There was, however, a significant difference between patients with mTBI and OI regarding age at injury and current age, with the patients in the OI group being younger (current age mean 18.4 years (SD 3.6), 15.8 years (SD 3.2), respectively; p<0.01)). Patients with OI had a significantly lower BMI (19.7 (SD 2.8) than the patients with mTBI (22.2 (SD 2.7), p<0.01) with both groups having a similar distribution of weight categories, predominantly in the normal weight range. There was a significant difference in the mechanism of the injury, in the mTBI group 49% of the injuries were sport-related, compared to 48% of the OI group having street/traffic related injuries (p=0.01) (Table 1).

Table 1. Characteristics of participants and non-participants with mild traumatic brain injury (mTBI) and orthopedic injury (OI).

	mTBI		OI	
	participants n=49	**non-participants n=257**	**participants n=54**	**non-participants n=267**
Sex, male; no. (%)	22 (45)	159 (62)	29 (54)	197 (74)
Age at injury, years; mean (SD)	16.8 (3.6) *	17.7 (3.6)	14.3 (3.2)	15.3 (3.5)
Time since injury, years; mean (SD)	1.6 (0.5)	1.8 (0.3)	1.5 (0.4)	1.8 (0.3)
Current age, years; mean (SD)	18.4 (3.6) *	19.5 (3.6)	15.8 (3.2)	17.1 (3.5)
Under 18 years, no. (%)	24 (49)	93 (36)	43 (80)	187 (70)
18 years and older, no. (%)	25 (51)	164 (64)	11 (20)	80 (30)
Location of injury; no. (%)				
home/school/work/other	14 (28)	73 (28)	15 (28)	76 (28)
street/traffic-related	11 (23)	39 (15)	26 (48)	136 (51)
sport/field	24 (49)	145 (57)	13 (24)	54 (20)
missing				1 (1)
BMI (kg /m²) [a]; mean (SD)	22.2 (2.7) *		19.7 (2.8)	
Underweight, no. (%)	4 (8)		10 (19)	
Normal weight, no. (%)	35 (72)		36 (67)	
Overweight, no. (%)	9 (18)		4 (7)	
Missing	1 (2)		4 (7)	

* $p<0.05$ between participants with mTBI and OI.
[a] Body Mass Index (BMI; weight (kg) / height squared (m^2)). Underweight is BMI under 18.5 above 18 years of age and under 17.0 for young adults under 18 years of age, normal weight 17.0/18.5-25.0, overweight 25.1-30.0, obesity above 30.0.
No BMI data was available for the non-participants.

Based on the unadjusted analyses for the AQuAA, patients with mTBI were significantly less active compared to patients with OI for moderate to vigorous activities (median 710 minutes/week (IQR 218-1105), median 945 minutes/week (IQR 645-1433), respectively; β -0.84, 95%CI -1.38, -0.30), with no significant difference in time spent on general activities or sedentary activities. Linear regression analyses adjusting for potential confounders sex, BMI, age, and time since injury show that having a mTBI was not significantly associated with general activities (β -0.31, 95%CI -0.66, 0.04), time spent on moderate to vigorous activities (β -0.58, 95%CI -1.19, 0.04) or sedentary activities (β -0.12, 95%CI -0.40, 0.17) (Table 2).
Significantly more patients with mTBI did not meet the D-HEPA recommendations (25 vs 16, OR 2.47, 95%CI 1.10, 5.56). The difference between the patients with mTBI and OI regarding the D-HEPA recommendations remained significant after adjusting for potential confounders (sex, BMI, age, and time since injury) in the logistic regression analysis (OR 2.87, 95%CI 1.07, 7.72).

Table 2. Physical activity (AQuAA) in a cohort of adolescents and young adults with mild traumatic brain injury (mTBI) compared to orthopedic controls (OI). Physical activity reported as minutes per week for general activities, moderate to vigorous activities and sedentary activities. Patients further categorized for meeting or not meeting the Dutch Health Enhancing Physical Activity (D-HEPA) recommendations.

	Unadjusted analyses			**Adjusted analyses**				
	mTBI n=49 Median (IQR)	**OI n=54 Median (IQR)**	**β (95%-CI)**	**mTBI injury β (95%-CI)**	**Female sex β (95%-CI)**	**BMI β (95%-CI)**	**Age β (95%-CI)**	**Time since injury β (95%-CI)**
AQuAA[a], min/week								
General activities, > 2 METS	1350 (755-2250)	1873 (1335-2561)	-0.28 (-0.57, 0.02)	-0.31 (-0.66, 0.04)	0.05 (-0.26, 0.37)	0.00 (-0.06, 0.07)	0.00 (-0.05, 0.06)	0.13 (-0.18, 0.45)
Moderate-vigorous activities, >5 METS	710 (218-1105)	945 (645-1433)	-0.84 (-1.38, -0.30)*	-0.58 (-1.19, 0.04)	-0.48 (-1.03, 0.08)	0.01 (-0.10, 0.13)	-0.10 (-0.19, -0.01)*	0.05(-0.50, 0.61)
Sedentary activities, < 2 METS	2670 (1750-4405)	3480 (2453-4454)	-0.22 (-0.46, 0.03)	-0.12 (-0.40, 0.17)	0.05 (-0.21, 0.31)	-0.05 (-0.10, 0.00)	0.01 (-0.03, 0.05)	-0.05 (-0.30, 0.21)
			OR (95%-CI)	**OR (95%-CI)**	**OR (95%-CI)**	**OR (95%-CI)**	**OR (95%-CI)**	**OR (95%-CI)**
Not meeting D-HEPA[b] recommendations, nr (%)	25 (51%)	16 (30%)	2.47 (1.10, 5.56)*	2.87 (1.07, 7.72)*	1.60 (0.66, 3.86)	1.11 (0.93, 1.32)	0.90 (0.78, 1.04)	0.53 (0.12, 2.30)

Linear regression analysis performed for the continuous variables on the natural logarithm of the data and reported as β and 95% CI and logistic regression analysis for the dichotomous variable (D-HEPA yes/no), reported as odds ratio (OR) and 95% confidence interval (CI). Analyses assess the relationship between type of injury (mTBI/OI; independent variable) and physical activity (dependent variable). Adjusted analyses correct for potential confounders: age, gender, BMI, and time since injury.

[a] Activity Questionnaire for Adults and Adolescents (AQuAA): 5 category self-assessment containing questions in the domains of commuting activities, household activities, leisure time and sport activities, activities at school and/or work, and sedentary activities. Data reported as medians and interquartile ranges (IQR).

[b] Dutch Health Enhancing Physical Activity recommendations (D-HEPA): children (≤ 17 years) meet the recommendation when performing moderate to vigorous (minimum 5 Metabolic Equivalent of Task (METS)) activities for a minimum of 60 minutes, 7 days a week. Adults (≥ 18years) meet the recommendation when performing moderate to vigorous (minimum 4 METS) activities for a minimum of 30 minutes, 5 days a week.

* $p< 0.05$

In the unadjusted analyses, patients with mTBI reported significantly higher levels of fatigue based on the CIS Total Score (β 16.87, 95%CI 7.71, 26.03), subscale Fatigue (β 7.77, 95%CI 3.31, 12.22), subscale Concentration (β 5.21, 95%CI 2.14, 8.29), and subscale Physical Activity (β 2.25, 95%CI 0.59, 3.92). After adjusting for potential confounders in the linear regression analyses only subscale Concentration remained significantly higher in the mTBI group (β 3.98, 95%CI 0.39, 7.56), indicating more concentration problems related to fatigue in this group. Based on the subscale Fatigue 16% of the mTBI group and 6% of the OI group were severely fatigued. In the unadjusted as well as the adjusted analyses the diffference between the two groups was not significant (Table 3).

In the unadjusted analysis, patients with mTBI reported significantly lower sleep quality based on the PSQI Total Score (β 1.34, 95%CI 0.22, 2.45) but this significance did not hold after adjusting for potential confounders in the adjusted analysis (β 0.82, 95%CI -0.49, 2.14). Thirty-seven percent of the mTBI group and 22% of the OI group reported poor sleep quality (PSQI Total Score greater than 5). The difference between the groups was not significant for the unadjusted or adjusted analyses (Table 3).

Table 3. Fatigue (CIS) and sleep quality (PSQI) in a cohort of adolescents and young adults with mild traumatic brain injury (mTBI) compared to orthopedic controls (OI).

		Unadjusted analyses			Adjusted analyses				
		mTBI n=49	OI n=54		mTBI injury	*Female sex*	*BMI*	*Age*	*Time since injury*
		Mean (SD)	Mean (SD)	β (95%-CI)	β (95%-CI)	β (95%-CI)	β (95%-CI)	β (95%-CI)	β (95%-CI)
CIS[a]	Total Score (range 20-140)	66.2 (24.8)	49.3 (22.1)	16.87 (7.71, 26.03)*	8.15 (-2.13, 18.42)	7.01 (-2.21, 16.23)	1.99 (0.13, 3.84)*	1.01 (-0.46, 2.49)	3.41 (-7.03, 13.86)
	Fatigue (range 8-56)	27.3 (12.3)	19.5 (10.5)	7.77 (3.31, 12.22)*	2.66 (-2.10, 7.42)	6.34 (2.06, 10.62)*	1.26 (0.40, 2.12)*	0.53 (-0.16, 1.21)	-0.10 (-4.94, 4.75)
	Concentration (range 5-35)	19.1 (8.0)	13.9 (7.8)	5.21 (2.14, 8.29)*	3.98 (0.39, 7.56)*	-1.29 (-4.51, 1.93)	0.38 (-0.27, 1.03)	0.05 (-0.46, 0.57)	1.83 (-1.82, 5.47)
	Motivation (range 4-28)	11.7 (5.4)	10.0 (5.1)	1.64 (-0.41, 3.68)	0.28 (-2.07, 2.63)	0.46 (-1.65, 2.56)	0.12 (-0.31, 0.54)	0.32 (-0.02, 0.66)	1.50 (-0.89, 3.89)
	Physical Activity (range 3-21)	8.1 (4.60)	5.9 (3.9)	2.25 (0.59, 3.92)*	1.18 (-0.74, 3.11)	1.53 (-0.20, 3.26)	0.26 (-0.09, 0.60)	0.10 (-0.17, 0.38)	0.16 (-1.80, 2.12)
PSQI[b]	Total Score (range 0-21)	5.4 (3.1)	4.0 (2.6)	1.34 (0.22, 2.45)*	0.82 (-0.49, 2.14)	0.59 (-059, 1.77)	0.14 (-0.10, 0.37)	0.03 (-0.16, 0.22)	0.26 (-1.08, 1.59)
				OR (95%-CI)	**OR (95%-CI)**	**OR (95%-CI)**	**OR (95%-CI)**	**OR (95%-CI)**	**OR (95%-CI)**
Severely fatigued based on CIS subscale Fatigue, nr (%)		8 (16%)	3 (6%)	3.32 (0.83, 13.31)	-0.30 (0.12, 4.63)	3.82 (3.62, 576.04)*	0.58 (1.19, 2.71)*	0.10 (0.86, 1.43)	-0.27 (0.05, 10.96)
Poor sleep quality, based on PSQI Total Score, nr (%)		18 (37%)	12 (22%)	2.03 (0.86, 4.83)	0.23 (0.45, 3.49)	0.38 (0.57, 3.72)	0.17 (0.98, 1.43)	-0.01 (0.86, 1.14)	0.21 (0.27, 5.66)

Analyses performed with linear regression analysis assessing the relationship between type of injury (mTBI/OI; independent variable) and fatigue/sleep quality (dependent variable) while correcting for potential confounders sex, BMI, age, and time since injury; results reported as β and 95% confidence interval (CI). Logistic regression analysis for the dichotomous variables (severe fatigue or sleep disorder, yes/no), reported as odds ratio (OR) and 95% CI; adjusted for the same confounders.

[a] Checklist Individual Strength (CIS): higher scores represent higher levels of fatigue. A score ≥ 40 on the subscale Fatigue indicates severe fatigue.

[b] Pittsburgh Sleep Quality Index (PSQI): higher scores represent lower sleep quality. A score > 5 on the Total Score indicates poor sleep quality.

* $p < 0.05$, ** $p < 0.001$

Discussion

This study comparing PA, fatigue and sleep in AYAs at least 6 months after mTBI and OI, recruited from the ED of 2 hospitals, found significantly less AYAs with mTBI meeting Dutch recommendations for physical activity than AYAs with an orthopedic injury. The two cohorts differed significantly in fatigue symptoms related to concentration but not on total amount of time spent on physical activity, other dimensions of fatigue or sleep quality.

Regarding the amount of PA and the proportion of patients meeting HEPA guidelines observed in the mTBI group, comparisons with the literature are difficult to make because it is the first study to look at quantitatively measured PA. Most of the literature on PA after mTBI reports outcomes in terms of return to play,[48] resumption of sport activities,[49] activity patterns[50] or capacity in general[15] instead of the amount of PA or meeting PA recommendations. A previous study, from our own research group, included AYAs with TBI who had taken part in a rehabilitation program, found that 50% of the AYAs with mTBI met D-HEPA recommendations[5] which is comparable to the current study with 49% of AYAs with mTBI meeting the D-HEPA recommendations. In the multivariate analyses increasing age was related to less time spent on moderate to vigorous activities, supporting earlier studies in this population.[23, 51]

Concerning fatigue, in this study we found significant differences between the mTBI and OI group regarding fatigue related to concentration. Only two other studies on the long-term, 2 years post injury, compared fatigue in children with mTBI to an orthopedic control group[25, 52] with other studies only reporting fatigue on the short-term.[9] These studies report contradictory results; in one study parents of the mTBI group (children aged 4-14 years) reported more fatigue than the OI group of the same age group[25] compared to no difference between the groups of 4-15 year old children in terms of frequency and severity of fatigue.[52] Concentration problems are more often reported by children with a post-concussion syndrome,[4] supporting our results. Fatigue is an often reported symptom in the AYA population[43] which may be reflected in our data with few differences between the mTBI and OI groups. In the multivariate analyses female sex was related to general fatigue, supporting earlier studies where female adolescents report more fatigue.[43] Increasing BMI was also related to total fatigue and general fatigue in our study population, supporting an earlier study done with adults aged 20-59 years.[53]

With respect to sleep quality, the observed absence of a difference between the mTBI and OI groups in the current study is similar to those found by Necajauskaite et al.,[52] in their cohort of 102 children aged 4-15 years compared to children with OI, with no significant difference between groups for frequency and severity of sleep disorders

27 months post injury. The mTBI group in another study by Tham et al.[54] initially reported more sleep disturbances compared to the OI control group with sleep disturbances returning to pre-injury baseline level over time (12 and 24 months post injury) supporting the non-significant difference found in our cohort. The results differ with a previous study where sleep quality in children with mTBI 1-year post-injury was significantly lower than healthy controls.[12] Discrepancies between studies in sleep quality may be explained by the time since injury or patient age in the study cohorts.

In this study, PA, fatigue and sleep quality were considered separately. The interrelationship among PA, fatigue and sleep disorders is complex.[55-57] It would require a profound theoretical background and the use of a large number of hypotheses considering all potential relationships, including all possibilities of one or more of these three factors mediating the effect of the other(s). For this reason this study did not focus on this complex interaction, but merely described and compared the three variables separately. Further research however would definitely need to explore the relationships between physical activity, fatigue and sleep quality in AYAs with a mTBI and possible causality leading to opportunities to develop more specific treatment programs.

Limitations and directions for future research

There are several limitations in this study. We only collected post-injury data and have no data concerning PA levels, fatigue or sleep quality before the trauma. In TBI research collection of such pre-injury data is not possible unless registry data or similar data from other sources are available, or retrospective reporting is used, which is prone to bias. Moreover, we did not use a control group from the general population, hampering the interpretation of the observations regarding PA, fatigue and sleep quality done in the two study populations. The response rate is low but is similar to other studies concerning TBI in children and adolescents.[58] Approaching patients closer to the time of injury/ED visit could increase the response rate. The sample size of this study was relatively small, with some patients deciding not to participate because of a lack of symptoms. It is conceivable that those patients were relatively active and/or did not have high levels of fatigue, so that both the proportions of inactive patients as well as the difference between the mTBI and OI groups may be overestimated. Further, there were relatively more girls than boys, both in the mTBI and OI groups, hampering the generalizability of the results. In addition, there were some differences between the general and injury characteristics between the mTBI and the OI groups, the latter having a significantly lower age and BMI, whereas it is known from the literature that PA levels decrease with age.[23] Although we adjusted for age and BMI in the multivariable analysis, confounding cannot be completely ruled out. Moreover, BMI data were obtained by means of self-report, where clinical measurement would have yielded more reliable results. There was also a significant difference regarding the mechanism of the injury, with sports injuries most common in the mTBI group and street/traffic related injuries in the OI group. The mechanism of injury can have secondary influences on functioning due to potential symptoms related to, e.g. a post-traumatic stress disorder, which were not taken into account in this study. Moreover, this study was performed in only one region of the Netherlands which limits the generalizability of the results to all Dutch AYA with TBI, or similar patients in other countries. Regarding the assessments, measuring PA and sleep only with subjective measures, i.e. questionnaires, may have given rise to report bias. For PA, the AQuAA was used, for which it was proven that its reliability is low and its validity in comparison with an accelerometer is poor [35] while on the other hand, it is the questionnaire used in the Netherlands by the Central Bureau for Statistics to gather health data from the general population. In the literature it is indeed concluded that both adolescents and adults underestimate the time spent on sedentary behavior and overestimate the time spent on PA.[35] Therefore, the use of accelerometers in addition to self-report questionnaires to quantify PA after TBI has been suggested and implemented in adult TBI studies.[59]

In addition, both for fatigue and sleep quality we used one particular instrument (i.e. the CIS and the PSQI), and it remains to be established to what extent with other measurement instruments, including objective measurements for sleep, different results would have been obtained.

Strengths of our study include the selection of patients from hospital registries and the use of a group patients with OI from the same hospitals in the same period. In addition, in our analyses we controlled for a substantial number of potential confounders, looking further than the injury itself.

Conclusions

Adolescents and young adults with mild TBI, at least 6 months post-injury, less often meet the Dutch health enhancing physical activity recommendations and report more concentration problems related to fatigue when compared to a control group with orthopedic injuries. Further research needs to explore the relationships between physical activity, fatigue and sleep quality in adolescents and young adults with a mTBI and possible causality leading to opportunities to develop more specific rehabilitation treatment programs.

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Declaration of interests

The authors report no conflicts of interests or financial support.

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