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Daily life physical activity and concussion symptoms in adolescents

Activité physique quotidienne et symptômes de commotion cérébrale chez les adolescents

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Key words: Concussion; Mild traumatic brain injury; Paediatrics; Physical activity; Symptoms.

Mots clés : Activité physique; Commotion cérébrale; Pédiatrie; Symptômes; Traumatisme crânien léger.

Abstract

Background. Concussion is a common injury in an adolescent population with up to 30% experiencing persistent symptoms. Rehabilitation programs that include aerobic exercises can reduce persistent postconcussion symptoms. However, it is unclear if daily life physical activities can also reduce symptoms. **Purpose.** To investigate whether the level of daily life physical activity reduces postconcussion symptoms in the adolescent population. **Methods.** Ten adolescents aged 11–18 years with a concussion self-reported their postconcussion symptoms and level of physical activity during the first, third, and sixth months after injury. The extent to which physical activity explained postconcussion health was analyzed using linear mixed-effects modeling. **Findings.** Higher levels of daily life physical activity were associated with fewer somatic and cognitive symptoms. **Implications.** These findings suggest that daily life physical activity, including engagement in sports, physical education, or active games, should be encouraged by occupational therapists to promote concussion recovery.

Abrégé

Description. La commotion cérébrale est une blessure courante chez les adolescents. Jusqu'à 30 % des adolescents ayant subi une commotion cérébrale ont des symptômes persistants. Les programmes de réadaptation qui comprennent des exercices aérobiques peuvent réduire les symptômes post-commotionnels persistants. Toutefois, on ne sait pas vraiment si les activités physiques quotidiennes peuvent également réduire ces symptômes. **But.** Déterminer si un certain niveau d'activité physique quotidienne réduit les symptômes post-commotionnels chez les adolescents ayant subi une commotion cérébrale. **Méthodologie.** Dix adolescents âgés de 11 à 18 ans ayant subi une commotion cérébrale ont déclaré leurs symptômes post-commotionnels et leur niveau d'activité physique pendant le premier mois, le troisième mois et le sixième mois suivant leur accident. La mesure selon laquelle l'activité physique pouvait expliquer la santé post-commotionnelle a été analysée à l'aide d'un modèle linéaire à effets mixtes. **Résultats.** Des niveaux élevés d'activité physique quotidienne ont été associés à une quantité moindre de symptômes somatiques et cognitifs. **Conséquences.** Ces résultats suggèrent que les ergothérapeutes devraient encourager les adolescents ayant subi une commotion cérébrale à faire de l'activité physique au quotidien, notamment du sport, de l'éducation physique ou des jeux actifs, afin de favoriser leur rétablissement post-commotionnel.

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Introduction

Concussion (i.e., mild traumatic brain injury) is a common injury and a major public health burden, particularly in the adolescent population as the developing brain is more vulnerable to injury (Rajabali et al., 2016). Rates of concussion can only be estimated; as previous studies have suggested, more than 55% of concussions are unreported (McCrea et al., 2004; Register-Mihalik et al., 2013; Wallace et al., 2017). However, even reported rates are high, occurring in up to 799 per 100,000 individuals (Macpherson et al., 2014). Adolescents (i.e., individuals aged 11–18 years) experience a disproportionately higher rate of concussions compared to younger and older ages (Rajabali et al., 2016).

Symptoms of concussion can include somatic (e.g., headache, dizziness), emotional (e.g., unstable mood, depression), physical (e.g., balance and visuo-ocular motor deficits), and cognitive complaints (e.g., inattention, forgetfulness; Barlow et al., 2010). Most adolescents who sustain a concussion experience symptom resolution within 2 weeks (Ayr et al., 2009; Barlow et al., 2011). However, approximately 30% experience symptoms that require more than 2 weeks to be resolved (Ayr et al., 2009; Zemek et al., 2016). These persistent symptoms can negatively impact various occupations such as school, work, and play (Barlow, 2014; Barlow et al., 2010; Iverson, 2005). Specifically, prolonged concussion symptoms and consequent activity limitations can negatively affect emotional control, influence academic and social roles, and impact self-perception (Sveen et al., 2016).

There are factors known to prolong recovery from concussion in a paediatric population, including female sex (Gauvin-Lepage et al., 2019), adolescent age, migraine history, prior concussion with symptoms > 1week, experience of headache, sensitivity to noise, and fatigue after concussion (Zemek et al., 2016). Research on factors that positively influence recovery trajectory is therefore needed.

There is a growing body of research describing the benefit of aerobic exercise to improve recovery after concussion in children, adolescents, and adults (Leddy et al., 2018; Leddy et al., 2019). Review articles report that aerobic exercise may improve indices of postconcussion symptoms and reduce the number of days off work (Hugentobler et al., 2019; Lal et al., 2018; Silverberg & Iverson, 2013). Specifically, adolescents who engaged in a rehabilitation program involving physical activity within the first month of concussion experienced reduced symptoms (Chrisman et al., 2017; Grool et al., 2016). Additionally, rehabilitation programs that included structured aerobic physical activity for adolescents with persistent symptoms beyond one month reduced these symptoms (Chen-Sang et al., 2020; Gagnon et al., 2009; Gagnon et al., 2016; Imhoff et al., 2016; Kurowski et al., 2017; Leddy et al., 2018; Leddy et al., 2019). Additionally, adolescents with persistent symptoms after concussion (e.g., > 1 month) who engaged in exercise-based rehabilitation reported significantly improved quality of life and reduced anger, with a trend toward reduction in symptoms, compared to participants who received standard care (Gauvin-Lepage et al., 2018). Finally, adolescents experienced positive changes in performance and satisfaction in leisure occupations after receiving active rehabilitation (e.g., physical activity in a rehabilitation setting; Chen-Sang et al., 2020). While primarily focusing on increasing physical activity, some of these active rehabilitation interventions also included other components, such as education and relaxation, that may have contributed to the observed effects.

Daily life physical activities include occupations completed within one’s typical routine, not part of a prescribed exercise or aerobic program. For youth after concussion, this could include participation in sports, physical education class or playing games during spare time. These activities may provide a sense of routine and may be linked to one’s self-identity and social participation (Beadle et al., 2016). Research is needed to understand how engagement in these daily life physical activities would influence recovery after concussion to inform ecologically driven clinical trials, guideline development, and client-centred practice recommendations. Given that physical activity, which includes exercise and sports, is an occupation that provides an outlet for leisure and productive activities in the adolescent population, safe engagement in these activities after concussion may promote an improved recovery trajectory (Sveen et al., 2016; Valovich McLeod et al., 2017).

Despite evidence supporting the benefit of physical activity on improvement of concussion symptoms, it remains unclear whether engagement in self-directed, daily life physical activities (i.e., outside of a structured rehabilitation program), is associated with fewer symptoms during the first 6 months postconcussion. Therefore, the objective of this study was to investigate the association between the engagement in daily life physical activity and concussion symptoms in adolescents.

Methods

Design

This cross-sectional study was conducted within a larger study, the Study of Neurophysiology In Childhood Concussion (SONICC). The Clinical Research Ethics Board (University of British Columbia) approved the study procedure (ID H16-01859) in accordance with the principles of the Declaration of Helsinki.

Participants

Participants were recruited through community advertisements and referrals from the BC Children’s Hospital Emergency Department. Inclusion criteria were age 11–18 years, experience of a physician-diagnosed concussion, and within 1-month postinjury. Participants were not involved in structured rehabilitation programs prior to or during the study period.

Variables

Concussion symptoms were measured using the Health and Behavior Inventory (HBI), with higher scores indicating poorer health (Ayr et al., 2009). This measure was completed by both the parent and the adolescent. The adolescent self-assessment version was used as the outcome. The parental version was used to control for the potential effect of parental assessment in the sensitivity analysis as their assessment could influence adolescents' self-assessment of the emotional and behavioural dimensions of their symptoms (Ayr et al., 2009). The HBI was chosen as it is a recommended core assessment for TBI symptoms (McCauley et al., 2012). It consists of 20 items that measure the frequency of common postconcussive symptoms. The HBI has sound psychometric properties with validity in distinguishing concussion from other injuries (Fay et al., 2010; Hajek et al., 2011).

Physical activity was measured using the Physical Activity Questionnaire for Adolescents (PAQ-A). The PAQ-A is a self-administered, 7-day recall questionnaire, completed by the adolescent. It includes a series of eight items designed to assess general levels of physical activity in adolescents at different times of schooldays (spare time, physical education classes, lunch, right after school, evenings) and during weekends (Kowalski et al., 1997). This includes sports or games that make the adolescents "breathe hard, like tag, skipping, running, climbing, and others" (Kowalski et al., 2004). For each item, a composite score ranging from 1 to 5 is computed based on physical activity frequency (e.g., I don't do physical education = 1, hardly ever = 2, sometimes = 3, quite often = 4, always = 5) or physical activity intensity (e.g., sat down = 1, stood or walked around = 2, ran or played a little bit = 3, ran around and played quite a bit = 4, ran and played hard most of the time = 5; Kowalski et al., 2004). The PAQ-A summary score is the mean of the 8 composite scores and was used to assess daily life physical activity in postconcussion adolescents, with higher scores indicating higher levels of physical activity.

Procedure

All participants and parents/guardians provided written informed assent and consent prior to data collection. All participants received an honorarium for participation. Measures were conducted during the first (21 $\pm$ 8 days), third (107 $\pm$ 14 days), and sixth month (199 $\pm$ 15 days) after injury. Participants and parents completed the outcome measures independently in their home, using paper-based versions of the assessments that were provided by the occupational therapy researcher. Participants responded to the questions independently.

Statistics

The extent to which physical activity explained symptoms during the first, third, and sixth month after concussion was analyzed using a linear mixed-effects model as seen in (1) where Adolescent HBI_{ij} is the self-assessed HBI score of the *jth* adolescent on session *i*, the β s are the fixed effect coefficients, u_{0j} is the random intercept for the *j*th participant, and ϵ_{ij} is the error term.

$$\text{Adolescent HBI}_{ij} = \beta_0 + \beta_1 \text{ Physical Activity}_{ij} \times \beta_2 \text{ Time Postconcussion}_{ij} + u_{0j} + \epsilon_{ij} \quad (1)$$

This linear mixed-effects model was built in R using the lme4 and lmerTest packages (Bates et al., 2015; Kuznetsova et al., 2016; R Core Team, 2019) and specified participants as a random factor. This conservative statistical analysis is often preferred to traditional analyses such as ANOVAs (Boisgontier & Cheval, 2016) because it avoids information loss due to averaging over participants (Judd et al., 2012), is less vulnerable to type 1 errors (Baayen et al., 2008), allows incomplete and unbalanced data to be used, continuous and categorical predictors to be combined, and the statistical assumptions underlying the use of these models can be met even with small samples of participants (Boisgontier & Cheval, 2016). Continuous variables were scaled and centred on zero. Restricted maximum likelihood (REML) was used as it provides less biased estimates of variance components than full maximum likelihood (Luke, 2017), especially in small samples (McNeish & Stapleton, 2016). *p* values were calculated based on Kenward-Roger's approximations for degrees of freedom (Kenward & Roger, 1997) to guard against the inflated type-I error rate that results from underestimated fixed-effect standard errors in small samples (McNeish & Stapleton, 2016). An estimate of the effect size of the fixed effects was reported using the marginal pseudo R^2 computed using the MuMIn package (Barton, 2018). Statistical assumptions associated with linear mixed-effects models (normality of the residuals, homogeneity of variance, linearity, multicollinearity, and undue influence) were checked and met for all models.

A sensitivity analysis adjusting for covariates likely to influence postconcussion symptoms and physical activity, such as age, gender, and the parental assessment of the symptoms (HBI) was also performed (2).

$$\begin{aligned}\text{Adolescent HBI}_{ij} = {} & \beta_0 + \beta_1 \text{ Physical Activity}_{ij} \\ & + \beta_2 \text{ Time Postconcussion}_{ij} + \beta_3 \text{ Age}_j \\ & + \beta_4 \text{ Gender}_j + \beta_5 \text{ Parental Assessment}_{ij} \\ & + u_{0j} + \epsilon_{ij}\end{aligned} \quad (2)$$

Findings

Participants were 10 adolescents (4 females, 6 males) aged 13.7 $\pm$ 1.9 years (mean $\pm$ SD) who sustained a concussion from a sport-related injury; five participants had experienced a previous concussion (Table 1). PAQ-A (1.9 $\pm$ 0.7) and HBI (16.4 $\pm$ 13.6) data for the participants at the 3 postconcussion

Table 1
Demographics and Injury-Related Variables, N = *10*

	Mean (SD)
Sex (number male, %)	6.6%
Age	13.7 (1.9)
Paediatric fatigue short form	23.5 (9.1)
SCAT (balance subscale)	
Errors	4.0 (3.4)†
Time (seconds)	12.0 (2.0)†

Note. SCAT = sport concussion assessment tool; †n = 9.

Table 2
*Self-reported Physical Activity (PAQ-A) and Postconcussion Symptoms (HBI) for All Participants (*N = *10) during the First, Third, and Sixth Month Postconcussion*

Observation	Participant	Age (years)	Month Postconcussion	HBI	PAQ-A
1	1	16	1	38	1.3
2	1	16	3	37	1.0
3	1	16	6	38	1.5
4	2	14	1	33	1.4
5	3	15	1	28	1.1
6	4	12	1	14	1.7
7	4	12	6	15	2.3
8	5	16	1	7	0.5
9	5	16	3	7	1.6
10	6	11	1	8	2.5
11	6	11	6	5	3.0
12	7	13	1	14	0.8
13	7	13	3	2	2.5
14	8	13	1	4	2.5
15	8	14	3	0	2.8
16	8	14	6	8	2.2
17	9	11	1	0	1.8
18	10	14	3	29	2.5
19	10	14	6	25	3.2

Note. HBI = Health and Behavior Inventory; PAQ-A = Physical Activity Questionnaire for Adolescents

assessments (n = 19 observations) are reported in Table 2 and illustrated in Figure 1 (scatter plot).

Results of the main model (1) showed a significant effect of physical activity on postconcussion symptoms (b = −4.638, SE = 1.489, pseudo R^2 = .109, p = .018) but no significant effect of time postconcussion (b = 1.509, SE = 1.035, pseudo R^2 = .031, p = .193), and no significant interaction (b = −.772, SE = 1.026, pseudo R^2 = .009, p = .479) (Table 3). These results showed that for every increase in physical activity by 1 standard deviation (SD = .76), postconcussion symptoms decreased by 4.638 units (Figure 1).

Results of the sensitivity analysis (2) adjusting for covariates including the time postconcussion (b = 1.955, SE = 1.791, .109, p = .330), age (b = 8.253, SE = 5.055, p = .144), sex (b = −10.834, SE = 7.815, p = .208), and the parental assessment of the symptoms (b = .882, SE = 1.954, p = .670) were consistent

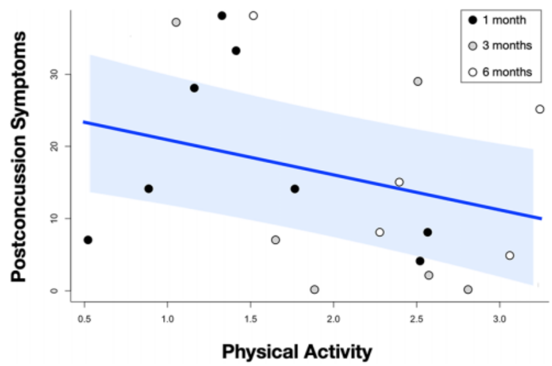

Figure 1. Fixed effect and the 95% confidence interval of physical activity (PAQ-A score) on self-assessed postconcussion symptoms (HBI) as estimated by the linear mixed-effects model. The scatter plot illustrates the raw data for all participants 1 month (black dots), 3 months (grey dots), and 6 months after concussion (white dots).

with the main results with a similar effect of physical activity on postconcussion symptoms (b = −4.817, SE = 1.898) although this effect was just below significance (p = .058).

Discussion

These findings reveal that engagement in daily life physical activity is associated with self-assessed symptoms in a concussed adolescent population. Current consensus statements, empirical research, and concussion guidelines support engagement in physical activity programs that are carefully supervised and monitored by trained personnel to improve recovery after concussion (Leddy et al., 2019; McCrory et al., 2017; Reed et al., 2019). Our findings support previous research on the benefits of active rehabilitation programs on concussion symptoms (Schneider et al., 2013). Our data also extends this previous research, suggesting that resumption of daily life physical activity such as sports, physical education, or games at different times of the day (spare time, physical education classes, lunch, right after school, evenings) and during weekend days, may also be positively related to concussion recovery.

In our study, physical activity was not conducted within a rehabilitation program. Instead, individuals re-engaged in normal daily life activities such as sports, playing with friends, and school-based programs. All adolescents in our sample sustained concussions from sport-related events, indicating adolescents' participation in physical activity as part of a normal routine of everyday life prior to the concussion. It is possible that participants re-engaged in personally relevant and meaningful activities, which could have additionally facilitated recovery (Tate et al., 2018).

Although evidence supports the role of physical activity (often conducted within a structured rehabilitation program) in facilitating recovery after concussion, the underlying mechanisms remain unclear. It is possible that physical activity directly promotes neurological recovery in a concussed adolescent population (Schmidt et al., 2018). Alternatively, individuals who

Table 3
Estimated Effects of Physical Activity (PAQ-A) and the Time Postconcussion on the Health and Behavior Inventory Score (HBI).

Fixed Effects	b (95CI)	SE	*p*	
Intercept	15.289 (7.270; 23.307)	4.091	.004	**
Physical activity	−4.638 (−7.558; −1.718)	1.489	.018	*
Time postconcussion	1.509 (−0.519; 3.539)	1.035	.193	
Physical activity × time postconcussion	−0.772 (−2.784; 1.239)	1.026	.479	
Random effect	σ^2			
Participant intercept	157.507			
Residual	6.364			

Note. HBI = Health and Behavior Inventory; PAQ-A = Physical Activity Questionnaire for Adolescents; 95CI = 95% confidence interval; SE = standard error; $^{**}p < .01$, $^{*}p < .05$.
Number of observations = 19, number of participants = 10.

re-integrate into personally meaningful life activities (including physical activities) experience minimal depressive symptoms, which in turn promotes a positive recovery framework. For example, the Activity Intolerance Cascade theorizes that individuals who do not re-engage in occupation will further self-limit engagement (DiFazio et al., 2016; Paniccia & Reed, 2017). Lastly, the resolution of symptoms after engagement in daily life physical activity may be due to participation and validation within established social networks (e.g., school, sports teams), which in turn provides intrinsic motivation for recovery (Stålnacke, 2007). In this way, individuals may have reduced vigilance on the experience of symptoms and a greater focus on returning to meaningful occupations, social networks, roles, and routines.

Limitations of this study include a small sample size, lack of comparative group, and lack of background information on participants. The small sample size may not reflect the larger population although we used conservative statistical analyses that accounted for this small number. This study did not include a comparative group. Thus, while showing an association between daily life physical activity engagement and symptom expression, no causation could be inferred. Lastly, the lack of pre-injury information did not allow us to account for aspects that might additionally relate to recovery (Zemek et al., 2016). Although we were able to account for age and sex, we did not collect data on previous migraine history or sensitivity to noise.

Further research is needed to understand how participation in occupations, including daily life physical activities, influence concussion recovery and symptom expression. As previously demonstrated, adolescents with concussion often experience negative alterations to occupational performance. Importantly, this can be mitigated through participation in a structured active rehabilitation program, indexed through occupational performance and satisfaction outcomes (Chen-Sang et al., 2020). Our findings indicate that daily life physical activity (i.e., outside a structured program) may positively influence symptom expression. Further research is needed to understand whether participation in personally relevant and meaningful occupations (e.g., non-physical leisure activity, school) can also improve recovery trajectories and decrease symptom expression. Additionally, research is needed to explore if these results can be generalized to other populations (e.g., younger children, adults).

These findings have important implications for occupational therapists who provide rehabilitation for adolescents with concussion. Based on this new evidenced association, occupational therapists who promote safe re-engagement in daily life physical activity occupations may positively influence concussion recovery. An occupation-based approach would facilitate effective concussion management, focusing on enabling clients to engage in meaningful physically active occupations within their specific contexts (Townsend & Polatajko, 2013).

Conclusion

Engagement in daily life physical activity is positively associated with concussion recovery as measured by reduced symptoms. These findings highlight the need for further research in the field of physical activity to investigate the individualized, client-centred, occupation-based approaches in concussion management outside of rehabilitation programs.

Key Message

Daily life physical activity may have an important role in concussion recovery (e.g., reduction of symptoms)

Author Contributions

MPB, JS conceived the study. JS collected the data. MPB, BC analyzed the data. MPB, JS drafted the manuscript.

Transparency

The lead authors affirm that the manuscript is an honest, accurate, and transparent account of the study being reported, that no important aspects of the study have been omitted, and that any discrepancies from the study as planned have been explained.

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