Exploring the association between cognitive activity and symptom resolution following concussion in adolescents aged 11–17 years

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ABSTRACT

Objective As opposed to postconcussion physical activity, the potential influence of cognitive activity on concussion recovery is not well characterised. This study evaluated the intensity and duration of daily cognitive activity reported by adolescents following concussion and examined the associations between these daily cognitive activities and postconcussion symptom duration.

Methods This study prospectively enrolled adolescents aged 11–17 years with a physician-confirmed concussion diagnosis within 72 hours of injury from the emergency department and affiliated concussion clinics. Participants were followed daily until symptom resolution or a maximum of 45 days postinjury to record their daily cognitive activity (intensity and duration) and postconcussion symptom scores.

Results Participants (n=83) sustained their concussion mostly during sports (84%), had a mean age of 14.2 years, and were primarily male (65%) and white (72%). Participants reported an average of 191 (SD=148), 166 (SD=151) and 38 (SD=61) minutes of low-intensity, moderate-intensity and high-intensity daily cognitive activity postconcussion while still being symptomatic. Every 10 standardised minutes per hour increase in moderate-intensity or high-intensity cognitive activities postconcussion was associated with a 22% greater rate of symptom resolution (adjusted hazard ratio (aHR) 1.22, 95% CI 1.01 to 1.47). Additionally, each extra day's delay in returning to school postconcussion was associated with an 8% lower rate of symptom resolution (aHR 0.92, 95% CI 0.85 to 0.99).

Conclusion In adolescents with concussion, more moderate-high intensity cognitive activity is associated with faster symptom resolution, and a delayed return to school is associated with slower symptom resolution. However, these relationships may be bidirectional and do not necessarily imply causality. Randomised controlled trials are needed to determine if exposure to early cognitive activity can promote concussion recovery in adolescents.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Research on paediatric concussion based on structured and controlled interventions has suggested earlier introduction of physical activity promotes recovery, but little is known about the intensity and duration of cognitive activity postconcussion and its potential influence on concussion recovery outcomes.

WHAT THIS STUDY ADDS

⇒ Increased time spent in moderate-intensity or high-intensity cognitive activities was associated with faster symptom resolution, especially for participants with lower postacute symptom scores. However, when these cognitive activities involved significant screen time (eg, surfing the internet or video/computer gaming) during the first week postinjury, slower symptom resolution was observed independent of cognitive activity intensity.

⇒ Delayed return to school postconcussion for either half or full days was associated with slower symptom resolution.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Clinical trials are needed to determine if moderate-high intensity cognitive activity can promote recovery from concussion, in a manner similar to physical activity.

INTRODUCTION

Previous clinical guidelines for adolescents with concussion have recommended complete physical and cognitive rest until symptom resolution[1] to avoid reinjury and reduce the metabolic demands on injured tissue.[2–5] However, recent clinical and experimental data have demonstrated that prolonged physical rest does little to improve functional outcomes, and the resulting isolation and withdrawal can have unintended physical, social and educational consequences.[6–11] The most up-to-date guidelines recommend an initial period of relative physical and cognitive rest postinjury (24–48 hours) followed by a gradual, progressive return to activity.[12 13] As a result, clinical management of paediatric concussion has shifted to prescribing earlier physical activity,[14 15] which shortens the duration of rest and does not require symptom resolution prior to engaging in activity.[15–18]

Despite concussions potentially having adverse effects on cognitive function, possibly affecting recovery and return to school (a fundamental activity for adolescents),[2 19 20] research to date has focused on the effects of physical activity and its relationship to symptom duration and concussion recovery.[14–18] Little has been reported on the intensity and duration of cognitive activity postconcussion and their relationship to concussion recovery among adolescents due to the heterogeneity of concussive injuries and resulting effects on cognition as well as the challenges in measuring and monitoring cognitive activity.[21–25] Thus, personalised cognitive activity guidelines are less frequently prescribed for adolescents with concussions.

The purpose of the current study was to describe the intensity and duration of daily cognitive activity reported by adolescents aged 11–17 years following concussion and examine the associations between daily cognitive activities and postconcussion symptom duration.

METHODS

Study design and procedures

This study used a prospective cohort design with repeated measures. Preinjury recruitment activities were conducted at local schools by distributing study information via schools' newsletters and websites and at preseason team meetings. On a physician-confirmed diagnosis of concussion in the emergency department (ED) or one of seven concussion clinics affiliated with a children's hospital located in central Ohio (USA), potential participants were introduced to the study. If interested, trained clinical research coordinators in the ED or athletic trainers in concussion clinics referred potential participants to the research team. After screening for eligibility, adolescents aged 11–17 years were enrolled, along with one of their parents/legal guardians ('parents'), within 72 hours of injury after obtaining written assent and consent.

Injury information and acute clinical presentation (eg, signs and symptoms, mental status) were assessed during the initial clinic visit as part of routine care. Participants were followed postconcussion until symptom resolution (being symptom-free or having symptoms return to preinjury levels as confirmed by a certified athletic trainer or physician) or a maximum of 45 days postinjury. Participants completed daily surveys remotely throughout their enrolment to record the intensity and duration of physical and cognitive activities as well as postconcussive symptoms (PCS). Detailed descriptions of the study and protocol are published elsewhere.[25 26] For this study, only the demographic and injury information collected at enrolment were included, along with daily PCS and cognitive activities collected via daily surveys. This report follows STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) reporting guidelines for observational studies.[27]

Study participants

Participants were adolescents ages 11–17 who sustained a physician-confirmed concussion. A concussion was defined as a mild traumatic brain injury induced by a blow to the head, neck, face or other part of the body, resulting in transient neurological deficit.[12 26] Adolescents were excluded if their injury (1) was accompanied by other trauma (eg, face or neck injury, bone fracture); (2) involved a penetrating injury; (3) required neurosurgical intervention or hospital admission or (4) resulted in a condition(s) that interfered with adolescents completing the study assessments (eg, affected eyesight). Two designated physicians reviewed each potential participant's information to ensure eligibility criteria were met.

Study variables and measures

Cognitive activity

Cognitive activity was defined as engaging in activities requiring attention or concentration.[23] Participants were asked to respond via daily surveys if they had engaged in any of the listed cognitive activities each day, and if yes, how many minutes they had engaged in each of these activities according to published mental activity diary metrics.[25 26] The list classified the cognitive activity as low-intensity (eg, listening to music/radio, pleasure reading, watching TV, surfing the internet, texting, making/receiving phone calls), moderate-intensity (eg, video/computer gaming, being present in the classroom during school without taking quizzes/tests or giving presentations, participating in after-school activities (excluding clubs and jobs), participating in a club, working a job) or high-intensity (eg, completing homework, taking a quiz or test, giving a presentation), with Cronbach's alpha of 0.53. An adolescent could perform multiple cognitive activities at the same time (eg, watching TV and making/receiving phone calls). In this case, intensity and duration of each activity was calculated regardless of whether they were performed simultaneously.

Postconcussive symptoms

PCSs were assessed daily by having adolescents complete the Post-Concussion Symptom Scale based on their current symptoms.[12] The scale consists of 22 symptoms, each rated from 0 (no symptoms) to 6 (severe), with total scores ranging 0–132. The Post-Concussion Symptom Scale is a commonly used concussion assessment tool among clinicians, with established reliability (α=0.93), construct validity and normative data.[12 28] At the initial clinical visit, adolescents reported PCS at the time of injury and current PCS.

Demographic and injury variables

Demographic and injury variables included age, sex, grade in school, whether an injury occurred in a sport, number of previous concussions, days from injury to return to school for either half or full day and days from injury to acute symptom resolution.

Equity, diversity and inclusion

Sex and race/ethnicity exclusions were not used in this study. No specific effort was made to include or exclude minorities. All eligible patients ages 11–17 with a physician-confirmed concussion diagnosis during the study period were approached. The authors are from a variety of career stages and clinical disciplines including 4 (40%) women.

Statistical analysis

Descriptive statistics were used to describe daily cognitive activity during recovery. For each participant, the proportion of cognitive activity per person-day (days reported engaging in a particular cognitive activity divided by total number of days in the study) and the proportion of minutes of daily cognitive activity (minutes spent on a particular cognitive activity on a given day divided by the total minutes spent on all cognitive activities on that day) were calculated. These proportions were standardised into 60 min (1 hour) of cognitive activities to allow for comparisons between and within participants. To examine the associations between daily cognitive activities and PCS duration, time-varying covariates Cox models were used, accounting for time-dependent covariates including intensity and duration of daily cognitive activities and daily PCS score, adjusting for sex, age, previous concussion and whether an injury was sports related. The effects of the intensity of cognitive activity and time on corresponding HRs of symptom resolution were estimated, along with their 95% CIs. The event of interest was symptom resolution and the survival time was the number of days from injury to symptom resolution or 45 days postinjury (censored). To assess the linearity and proportional hazards assumption for each predictor identified, the cumulative martingale residuals against time were plotted and the Kolmogorov-type supremum test was calculated based on a sample of 500 simulated residual patterns. The final time-varying covariates Cox model was fitted with the minutes of moderate/high-intensity cognitive activities in a standardised hour as a continuous variable. Further analysis was conducted using similar proportional Cox models to assess the effects of days from injury to return to school and standardised minutes of each cognitive activity per hour on symptom duration. All analyses were conducted between November 2022 and May 2023 using SAS, V.9.4. Statistical significance was determined by $\alpha=0.05$.

RESULTS

Characteristics of participants

Of 83 concussed adolescents included in the analysis, average age was 14.2 years (SD=1.9), 54 (65%) were male, 60 (72%) were white and 41 (47.5%) enrolled from the ED. Most concussions (n=70, 84%) were sustained during sports, including 32.5% from American football and 15.7% from wrestling. All 13 (16%) non-sport-related concussions were enrolled from the ED. Seventy (84%) participants achieved symptom resolution by 28 days postconcussion.

Intensity and duration of daily cognitive activities postconcussion over time

Participants reported an average of 191 (SD=148), 166 (SD=151) and 38 (SD=61) minutes of low-intensity, moderate-intensity and high-intensity daily cognitive activities postconcussion while still symptomatic, respectively (table 1). In standardised minutes, these values correspond to 33 min of low-intensity, 22 min of moderate-intensity and 5 min of high-intensity daily cognitive activities per standardised hour. The most frequently reported low-intensity daily cognitive activity was listening to music (daily average of 44 min, 81% of person-days), followed by texting (37 min daily, 79% of person-days) and watching TV (50 min daily, 77% of person-days). The most often reported moderate-intensity cognitive activity was being in the classroom during school (106 min daily, 52% of person-days), followed by video/computer gaming (27 min daily, 42% of person-days). The most reported high-intensity cognitive activity was completing homework (28 min daily, 45% of person-days) (table 1).

Participants reported consistently greater average minutes of low-intensity cognitive activities while still being symptomatic during concussion recovery, followed by moderate-intensity and then high-intensity cognitive activities (figure 1).

Associations between daily cognitive activity and concussion symptom duration

Adjusting for relevant covariates, increasing time spent on moderate-intensity or high-intensity cognitive activities in one standardised cognitive activity hour was associated with faster symptom resolution (table 2). Specifically, every 10 standardised minutes increase per hour in moderate-intensity or high-intensity cognitive activities postconcussion was associated with a 22% greater rate of symptom resolution (aHR 1.22, 95% CI 1.01 to 1.47).

Table 1 Low-intensity, moderate-intensity and high-intensity daily cognitive activities postconcussion: proportion of person-day, minutes per day and minutes per one standardised hour

	Proportion of person-day*	Minutes per day		Minutes per standardised hour†	
	%	Mean	SD	Mean	SD
Low-intensity cognitive activities	**96.4**	**191.2**	**147.6**	**33.1**	**18.0**
Listening to music/radio	81.4	44.2	49.9	7.7	8.8
Pleasure reading	32.4	11.6	27.0	1.9	4.9
Watching TV	76.8	50.2	56.1	10.0	12.1
Surfing the internet	65.6	31.8	44.0	4.9	5.9
Texting	79.1	37.2	49.5	6.0	6.4
Making/receiving phone calls	45.9	16.1	31.2	2.6	4.9
Moderate-intensity cognitive activities	**74.7**	**165.7**	**150.9**	**22.0**	**16.7**
Video/computer gaming	41.5	26.7	47.1	4.6	7.9
Being present in the classroom during school	52.0	105.9	112.8	13.7	14.9
Participating after-school activities (excluding clubs and jobs)	22.6	27.9	61.4	3.1	6.7
Participating in a club	2.5	1.5	14.0	0.1	1.1
Working a job	2.5	3.8	27.8	0.5	4.1
High-intensity cognitive activities	**48.7**	**38.1**	**61.2**	**4.9**	**7.2**
Completing homework	44.9	27.7	45.3	3.7	6.1
Taking a quiz or test	23.3	9.7	25.9	1.1	2.8
Giving a presentation	2.5	0.7	7.7	0.1	0.9

Bold values indicates subtotals of each intensity level of cognitive activity.
*Days participants reported engaging in a particular cognitive activity divided by total number of days in the study.
†Proportion of minutes spent on a particular cognitive activity on a given day divided by the total minutes spent on all cognitive activities on that day, multiplied by 60 to standardise the proportion into one standardised hour.

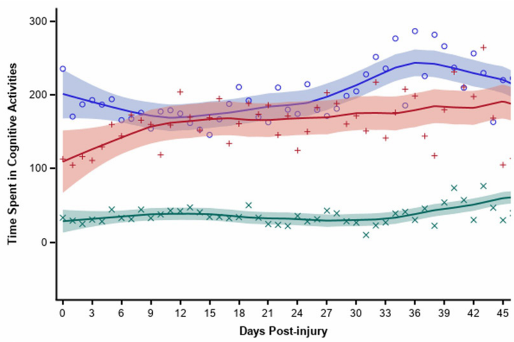

Figure 1 Daily average minutes spent on low-intensity, moderate-intensity and high-intensity cognitive activities postconcussion ■, ■, ■ (blue, red, green line and band) represents the low-intensity, moderate-intensity and high-intensity cognitive activities and their corresponding 95% CI, respectively. ○, ✚, ✕ represents the average minutes spent in low-intensity, moderate-intensity and high-intensity cognitive activities respectively in each day postinjury.

The average time until returning to half-day or full-day school was 4.5 (SD=3.2) days. Each day delay in returning to school postconcussion for either half or full days was associated with an 8% lower rate of symptom resolution (aHR 0.92, 95% CI 0.853 to 0.99) (table 3).

Associations between minutes of each cognitive activity during the first week postconcussion and symptom duration

The unadjusted analysis showed that during the first week postconcussion, every 10 standardised minutes increase per hour being present in the classroom was associated with 12%, greater rate of symptom resolution (HR 1.12, 95% CI 1.04 to 1.19), and every 10 standardised minutes increase per hour in participating in club activities was associated with 75% greater rate of symptom resolution (HR 1.75, 95% CI 1.14 to 2.68) (table 4). When stratified by PCS score at injury, for youth with PCS scores at injury below the median score of 44, an increase in every standardised 10 min per hour in engagement in video or computer gaming was associated with 29% lower rate of symptom resolution (HR 0.71, 95% CI 0.52 to 0.97), while an increase in time being present in the classroom was associated with 14% greater rate of symptom resolution (HR 1.14, 95% CI 1.06 to 1.24). For youth with PCS scores at injury equal or above the median score of 44, increased time surfing the internet and completing homework was associated with 24% and 20% lower rate of symptom resolution, respectively, while increased time watching TV or working a job was associated with 10% and 36% greater rate of symptom resolution, respectively.

DISCUSSION

This study investigated the associations between self-reported daily cognitive activities and symptom resolution among adolescents ages 11–17 who sustained a concussion. Participants reported increases in low-intensity cognitive activities and total minutes of overall cognitive activities as their symptoms resolved. While both moderate-intensity and high-intensity cognitive activities remained relatively low postconcussion, increased time spent in moderate-intensity or high-intensity cognitive activities was associated with faster symptom resolution. Delaying return to school was associated with slower symptom resolution. Finally, increased engagement in school-related activities during the first week postconcussion was associated with faster symptom resolution; this may be especially so for adolescents with lower postacute symptom scores. These findings add to the current literature by reporting the intensity and duration of cognitive activity postconcussion among adolescents during their recovery. Despite the challenges in measuring cognitive activities postconcussion,[22 23] the findings demonstrate the importance of documenting these activities. Such information could help inform physicians' recommendations regarding what level of cognitive activity adolescents should engage in for optimal concussion recovery.[23–25]

Nearly 97% of adolescents reported engaging in low-intensity cognitive activity during the first week postconcussion, averaging 33 min per standardised cognitive activity hour. The most common low-intensity cognitive activities during the first week postconcussion included listening to music/radio (77%), watching TV (75%) and texting (72%), none of which were associated with delayed symptom resolution. However, spending too much time surfing the internet or playing video/computing games could hamper recovery. These findings suggest that low-intensity cognitive activities such as listening to music, watching TV and texting may be permitted in the days following concussion but gaming and surfing the internet for more than a few minutes should be discouraged.

Evidence suggests engaging in high levels of activity, including screen time,[29 30] too soon after a concussion could exacerbate symptoms and lead to greater neurocognitive and functional impairment.[21 22 31 32] Conversely, 'complete' (physical and cognitive) rest may be impractical and could affect adolescents negatively because of muscular deconditioning and withdrawal from school and/or activities.[10 11 26] A randomised trial showed that 5 days of prescribed strict rest at home offered no additional benefits compared with usual prescribed care.[10] The studies that led to recommendations on using exercise prescription in concussion management were based on controlled trials using subthreshold exercise as an intervention.[11] Similar studies are required to determine the benefits (if any) of exposure to

Table 2 Moderate-intensity or high-intensity cognitive activities postconcussion and HR of symptom resolution

	Parameter estimate	Adjusted HR*	95% CI		P value
Every 10 min of moderate-intensity or high- intensity cognitive activities per standardised hour	0.02	1.22	1.01	1.47	0.04
Sex (male vs female)	−0.30	0.74	0.45	1.24	0.25
Age (year)	0.18	1.20	0.99	1.45	0.06
Previous concussion (yes vs no)	0.33	1.39	0.78	2.46	0.26
Injured in sport (yes vs no)	−0.29	0.75	0.28	2.01	0.56
Daily postconcussion symptom score†	−0.17	0.84	0.78	0.91	0.00

*HR adjusted for all the variables listed in table including sex, age, previous concussion, whether an injury was sport related and daily postconcussion symptom score.
†Daily cognitive activity and daily postconcussion symptom score were fitted as time-varying covariates in the model.

Table 3 Days to return-to-school since concussion and HR of symptom resolution

Predictors	Parameter estimate	Adjusted HR*	95% CI		P value
No of days between injury and return-to-school†	−0.08	0.92	0.85	0.99	0.03
Sex (male vs female)	−0.46	0.63	0.41	0.98	0.04
Age (year)	0.16	1.17	0.97	1.41	0.11
Previous concussion (yes vs no)	0.36	1.43	0.84	2.45	0.19
Injured in sport (yes vs no)	0.07	1.07	0.31	3.67	0.91
Daily postconcussion symptom score‡	−0.17	0.84	0.78	0.91	0.00

*HR adjusted for all the variables listed in table including sex, age, previous concussion, whether an injury was sport related and daily postconcussion symptom score.
†Return to school half day or full day since injury.
‡Daily cognitive activity and daily postconcussion symptom score were fitted as time-varying covariates in the model.

differing intensities and durations of cognitive activities postconcussion. While cognitive activity postinjury could help adolescents connect with their peers and friends, results from this study, along with those from others,[23–26] call for more research including structured and controlled cognitive activity interventions to identify optimal intensity, duration and type of cognitive activity postconcussion among adolescents to promote recovery.

Most published studies have focused on the effects of physical, rather than cognitive, activity on concussion recovery[11 12] despite cognitive activity being a foundational activity required in school. This is possibly due to much of the research being on sport-related concussion where return-to-play is an important endpoint and the relative ease of structuring an incremental exercise test (eg, Buffalo Concussion Treadmill Test) as an intervention.[7 11]

Having a better understanding of the appropriate 'dosing' and timing of introducing cognitive activity is critically needed for adolescents. This study found that every additional 10 standardised minutes per hour spent on moderate-intensity or high-intensity cognitive activities was associated with an increased recovery rate of 22%. Increased engagement in the classroom during the first week, especially for youth with PCS scores below the median at injury, was associated with faster symptom resolution. Few studies examining the benefit of early introduction of cognitive activity have produced mixed findings, with some showing that an early, gradual increase in cognitive activity, symptoms permitting, helped improve recovery outcomes postconcussion,[33] while others demonstrated a need for cognitive rest to avoid increasing symptoms.[23] A 2020 systematic review concluded that short rest periods and graduated physical and cognitive activity may best facilitate recovery from a concussion, but extended rest may prolong recovery time and increase symptoms.[34] Others found patients with no limited cognitive activity took longer to recover than those with limited cognitive activity days.[23] The relationship between level of cognitive activity and symptom resolution may be bidirectional, with improving postconcussion symptoms prompting higher levels of cognitive activity and vice versa.[35] Thus, controlling for current symptom levels when assessing associations between cognitive activity and symptom resolution, as this study did, is crucial. Given concussion recovery trajectories vary by individual, research on postconcussion cognitive activity should consider the individual's symptoms and tolerance for cognitive work.[2 36–38] While this study did not assess optimal cognitive rest postinjury, the findings suggest engaging in cognitive activities above low-intensity may help prompt recovery. However, such associations do not necessarily imply causality. Further randomised controlled trials are needed to confirm these findings.

Consistent with recent studies,[39] this study found that participants who delayed their return to school experienced longer symptom duration. Each additional day of delayed return was associated with 8% lower rate of symptom resolution. The

Table 4 Cognitive activities during the first week postconcussion and unadjusted HR of symptom resolution by postconcussion symptom score at injury

	Overall			PCS score at injury <44*			PCS score at injury ≥44		
	HR	95% CI		HR	95% CI		HR	95% CI	
Listening to music/radio	0.97	0.88	1.07	0.89	0.73	1.09	1.02	0.92	1.14
Pleasure reading	0.93	0.76	1.14	1.02	0.79	1.33	0.88	0.63	1.23
Watching TV	1.05	0.98	1.12	0.93	0.79	1.10	1.10	1.03	1.19
Surfing the internet	0.87	0.73	1.02	0.98	0.78	1.23	0.76	0.60	0.97
Texting	0.97	0.85	1.11	1.00	0.83	1.20	0.94	0.78	1.14
Making/receiving phone calls	1.01	0.83	1.24	1.17	0.95	1.44	0.89	0.65	1.24
Video/computer gaming	0.85	0.71	1.02	**0.71**	0.52	0.97	1.00	0.86	1.16
Being present in the classroom during school	1.12	1.04	1.19	1.14	1.06	1.24	1.07	0.96	1.20
Participating after-school activities (excluding clubs and jobs)	0.98	0.84	1.14	1.03	0.83	1.27	0.91	0.72	1.14
Participating in a club	1.75	1.14	2.68	1.79	0.26	2.76	0.84	0.03	23.35
Working a job	0.84	0.57	1.23	0.61	0.33	1.13	1.36	1.25	1.48
Completing homework	0.89	0.74	1.07	1.06	0.81	1.39	0.80	0.64	0.99
Taking a quiz or test	1.21	0.83	1.75	1.20	0.68	2.12	1.30	0.84	2.02
Giving a presentation	0.29	0.06	1.51	0.34	0.07	1.63	NA	NA	NA

*Median postconcussion symptom at injury was 44.
NA, not available; PCS, postconcussive symptom.

Brain Injury Association of America's 'Return to Learn Protocol' outlines a three-step recovery plan for returning to school.[34 40 41] The first phase includes complete physical and cognitive rest for 3 days or less if the student is symptom-free for 24 hours. The second step includes light thinking activities. The third phase starts with half-days or attending school part time before returning to school full time. This process aligns with the Centers for Disease Control and Prevention concussion management guidelines,[13] suggesting that students work with school staff to set accommodations without exacerbating symptoms.[42 43] These return-to-school guidelines are not strongly evidence based.[34] Findings from this study support previous research that earlier return to school is associated with shorter PCS duration.[42] Additional research is needed to provide an evidence-based 'Return to School' protocol after a concussion.

Clinical implications

Adolescents with concussion, especially those with relatively less severe postacute symptoms, may benefit from prescribed moderate-intensity to high-intensity cognitive activity as early as the first week postinjury. Further, limiting (but not prohibiting) moderate-intensity activities involving significant screen time (eg, surfing the internet or video/computer gaming) during the first week postinjury may help speed recovery. Finally, an early introduction of returning to school following concussion is an important consideration that may hasten timelines for recovery. Clinical trials are needed to determine if early engagement in moderate-high intensity cognitive activity can promote recovery from concussion, in a manner similar to early introduction of physical activity.

Limitations

First, this study's small sample size lacks diversity, as most participants were male, white, injured in a sporting activity and all participants were from a single hospital-based ED and concussion clinics, which may be referral centres for more severe concussive injuries. The results may not be generalisable to other populations of concussed adolescents. Second, the measures of daily intensity and duration of cognitive activity were based on self-report, which might either underestimate or overestimate the level of actual activities. The daily cognitive activities were reported only by adolescents who were still symptomatic because the follow-up ended at symptom resolution. Thus, results should be interpreted within that context. Third, preexisting conditions including history of depression and anxiety or developmental conditions, as well as baseline cognitive function and school achievement, may impact symptom magnitude and duration. However, such data were not collected in this study. Fourth, data on participants' acute injury severity (eg, the Glasgow Coma Scale and/or structural imaging data) were not available, and thus could not be used for inclusion/exclusion criteria in the study. Fifth, this study examined the intensity of cognitive activity without measuring the level of perceived exertion or engagement. Finally, while this study treated the level of cognitive activity as an independent variable and symptom resolution as a dependent variable, the relations between these two could be bidirectional. Further research experimentally varying intensity and duration of cognitive activity in a randomised controlled trial is required to establish the causal relationship.

CONCLUSION

Adolescents diagnosed with concussion primarily engage in low-intensity cognitive activity that progressively increases in the weeks following their injury, whereas their engagement in moderate-intensity and high-intensity cognitive activity remains relatively low during the same time frame. However, adolescents who engage in moderate-intensity to high-intensity cognitive activity, including engaging in some school activities during the first week postinjury, may have faster symptom resolution. Adolescents delaying their return to school may have slower symptom resolution. Additional studies are needed using randomised control trials to identify optimal levels of cognitive activity following a concussion that promote concussion recovery in adolescents.

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