Effect of Cognitive Activity Level on Duration of Post-Concussion Symptoms

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KEY WORDS

concussion, post-concussion syndrome, sports medicine, mild traumatic brain injury

ABBREVIATIONS

ATP—Adenosine triphosphate
PCSS—Post-Concussion Symptom Scale

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WHAT'S KNOWN ON THIS SUBJECT: Cognitive rest is recommended for the management of sport-related concussions. There are limited data to support this recommendation.

WHAT THIS STUDY ADDS: This study adds empirical data supporting the recommendation for cognitive rest after a sport-related concussion.

abstract

OBJECTIVE: To determine the effect of cognitive activity level on duration of post-concussion symptoms.

METHODS: We conducted a prospective cohort study of patients who presented to a Sports Concussion Clinic within 3 weeks of injury between October 2009 and July 2011. At each visit, patients completed a scale that recorded their average level of cognitive activity since the previous visit. The product of cognitive activity level and days between visits (cognitive activity-days) was calculated and divided into quartiles. Kaplan-Meier Product Limit method was used to generate curves of symptom duration based on cognitive activity level. To adjust for other possible predictors of concussion recovery, we constructed a Cox proportional hazard model with cognitive activity-days as the main predictor.

RESULTS: Of the 335 patients included in the study, 62% were male, 19% reported a loss of consciousness, and 37% reported experiencing amnesia at the time of injury. The mean age of participants was 15 years (range, 8–23) and the mean number of previous concussions was 0.76; 39% of athletes had sustained a previous concussion. The mean Post-Concussion Symptom Scale score at the initial visit was 30 (SD, 26). The overall mean duration of symptoms was 43 days (SD, 53). Of all variables assessed, only total symptom burden at initial visit and cognitive activity level were independently associated with duration of symptoms.

CONCLUSIONS: Increased cognitive activity is associated with longer recovery from concussion. This study supports the use of cognitive rest and adds to the current consensus opinion. *Pediatrics* 2014;133:e299–e304

Cognitive rest is often recommended as treatment of concussion. There are, however, limited data to support this recommendation. Current guidelines, including those from the American Academy of Pediatrics, the American Medical Society for Sports Medicine, the American College of Sports Medicine, and the American Academy of Neurology all recommend cognitive rest during the initial stages of recovery from concussion.[1–4] In addition, the recently published summary and agreement statement from the Fourth International Conference on Concussion in Sport again recommended cognitive rest, while acknowledging the need for further research, specifically stating "the current published evidence evaluating the effect of rest following a sports-related concussion is sparse. Further research to evaluate the long-term outcome of rest, and the optimal amount and type of rest, is needed."[5]

Of the limited research currently available, at least 3 studies have assessed the effect of cognitive rest. Moser et al assessed the timing of cognitive and physical rest on recovery from concussion, and suggested that regardless of when rest is implemented, a period of cognitive and physical rest may be a useful means of treating concussion-related symptoms.[6] Majerske et al assessed the effect of activity level after concussion on recovery, showing that athletes who engaged in high levels of activity after concussion demonstrated worse neurocognitive performance than those who had lower levels of activity. As physical activity and cognitive activity were assessed together, the independent effect of cognitive activity could not be assessed.[7] Lastly, in a retrospective chart review, Gibson et al assessed the effect of recommending cognitive rest to athletes suffering from concussion on duration of symptoms. They found no statistically significant association between the recommendation of cognitive rest and symptom duration.[8] In this study, we sought to assess the independent effect of cognitive activity on concussion symptom duration in a prospective cohort.

METHODS

Research Design

We conducted a single-center, prospective, cohort study of patients who presented to the Sports Concussion Clinic of Boston Children's Hospital between October 1, 2009 and July 31, 2011. Patients who presented within 3 weeks of injury, completed the intake form, and completed all follow-up forms were considered for enrollment in the study. We included patients who were diagnosed with a sport-related concussion or concussion resulting from a similar mechanism, such as a fall at a playground. We excluded those who had incomplete medical records, patients in whom alternate diagnoses were being considered, and patients who had more severe injury mechanisms, such as motor vehicle accidents or falls from above ground level. Standardized intake and follow-up forms were completed by the patient, including demographic characteristics (eg, age, gender) and clinical data (eg, date of injury, sport played at time of injury, Post-Concussion Symptom Scale [PCSS] score, cognitive activity scale) at each clinical visit.

Definitions

We used the definition of concussion proposed by the International Consensus on Concussion in Sports. Thus, applying this definition in a clinical setting, athletes who experienced a traumatic acceleration of the brain followed by the onset of symptoms of concussion, signs of concussion, or changes in neurocognitive function were diagnosed with a concussion.[5]

Athletes were considered recovered when (1) they were symptom-free at rest, (2) they were symptom-free with exertion and after discontinuing medications prescribed for post-concussion symptoms, (3) their balance error symptom scores were back to baseline, when available, and (4) their computerized neurocognitive test scores were at or above baseline values, when available. When baseline neurocognitive data were unavailable, scores within the age-adjusted published norms and consistent with estimates of premorbid levels of functioning were used. As is standard practice for neuropsychologists, estimates of levels of premorbid function are made by eliciting history regarding previous neuropsychological testing, academic performance, patient subjective reporting, and parental observations.

Balance error scores and computerized neurocognitive assessments are not routinely performed outside of the office and typically occur only at clinic visits. Therefore, it is difficult to know when actual recovery, as defined by the criteria above, occurred; we were only able to determine if athletes had met the recovery criteria at the time of their next clinic visit. We therefore used the duration of post-concussion symptoms as our primary outcome. The duration of post-concussion symptoms was defined as the time between the date of injury and the athlete's last date of symptoms, which was queried at each clinic visit.

Assessments

The PCSS, developed by the first International Consensus on Concussion in Sports, consists of 22 symptoms that athletes rate from 0, when the patient experiences no symptoms, to 6, when the patient experiences severe symptoms.[9] The PCSS is included in the Sport Concussion Assessment Tool version 2. The total PCSS score is the sum of the individual values, with a possible range from 0 to 132. As we were only interested in the symptoms caused by their injury, athletes were instructed to rate only those symptoms that started at the time of their concussion and that they were still experiencing within the 24 hours before their clinic visit. Symptom-free was defined as a post-concussion symptom score of 0. Athletes recorded the date they last had symptoms on the same page as the PCSS. Cognitive activity level was estimated by using a scale (Table 1) developed by 2 clinician-researchers experienced in concussion management. Athletes reported their cognitive activity level at each follow-up visit. Cognitive activity-days were then calculated by multiplying the average cognitive activity level reported by the patient by the days between visits.

Statistical Analysis

The outcome variable was the duration of concussion symptoms. The main predictor variable was cognitive activity-days. For univariate modeling, we divided cognitive activity-days into quartiles, using Kaplan-Meier analysis with log-rank tests of significance to evaluate the effect of cognitive activity-days on time to symptom resolution. As opposed to survival, as is more commonly represented by Kaplan Meier curves, the curve in our analysis reflects persistence of symptoms. To evaluate the effect of other potential predictor variables on symptom duration, we constructed a multivariate Cox proportional hazard model that included cognitive activity-days, age, gender, number of previous concussions, total initial PCSS score, amnesia at time of injury, and loss of consciousness at time of injury. To further assess for the potential effect of age, an analysis of variance was used to compare mean symptom duration for 3 separate age categories: school age (6–12 years), junior high/high school age (13–18 years), and adult (>18 years). Results are reported as mean ± SD. Statistical significance was defined as $P < .05$ or a hazard ratio with a 95% confidence interval that did not contain 1. All statistical analyses were performed using IBM SPSS Statistics 18.0 (SPSS, Inc, Chicago, IL) and Stata 10.1 (StataCorp, College Station, TX). This study was approved by the institutional review board of Boston Children's Hospital.

RESULTS

During the study period, 1124 patients were seen in clinic with the diagnosis of concussion. Of those, 119 were excluded for having a more severe mechanism of injury than sport-related concussion. An additional 80 had no reliable date of injury recorded and 395 presented >21 days from the date of injury. Two athletes were symptom-free at the time of their first appointment and 193 did not complete the cognitive activity scale. Thus, 335 participants were included in our analyses.

Participants ranged from age 8 to 23 years, with a mean age of 15 ± 2.6 years; 62% were male. The mean PCSS score at the initial clinical evaluation was 30 ± 26 days. The overall mean duration of symptoms was 43 ± 53 days. The mean difference in symptom duration did not differ significantly between school age (42 ± 39 days), junior high/high school age (43 ± 55 days), or adult (39 ± 60 days) athletes (P = .947). Thirty-nine percent of the athletes reported at least 1 previous concussion; the mean previous number of concussions reported was 0.76. Nineteen percent of patients reported a loss of consciousness at the time of injury, while 37% reported amnesia. Most concussions occurred while playing ice hockey, American football, basketball, and soccer (Table 2).

On univariate modeling, patients in the highest quartile of cognitive activity-days took statistically longer to recover than those in first to third quartiles of cognitive activity-days (Fig 1). On multivariate Cox proportional hazards modeling,

TABLE 1 Cognitive Activity Scale

0	Complete cognitive rest	No reading, homework, text messaging, video game playing, online activity, crossword puzzles, or similar activities. The most stimulating activities at this level would be watching television, watching movies, or listening to music.
1	Minimal cognitive activity	No reading, homework, crossword puzzles, or similar activities. Less than 5 text messages per day, less than 20 min per day combined of online activity and video games.
2	Moderate cognitive activity	Reading less than 10 pages per day, less than 20 text messages per day, and doing less than 1 h combined of homework, online activity, and video games per day.
3	Significant cognitive activity	Reading less, doing less homework, working less online, text messaging less, and doing crossword or other activities than you would normally do, but more than listed in level 2.
4	Full cognitive activity	You have not limited cognitive activity at all.

Patients were given the following instructions: "Cognitive activities are those activities which require you to think harder than usual. Homework, reading, playing video games, text messaging, doing crossword puzzles, playing trivia games and working online are all forms of cognitive activity. Below is a scale, from 0-4, of various levels of cognitive activity. Using the scale, please circle the average level of cognitive activity you have participated in since your last visit."

TABLE 2 Sports Played by Participants

Sport	Percentage of Participants
Ice hockey	21.8
American football	20.6
Basketball	14.9
Soccer	13.4
Lacrosse	6.0
Skiing/snowboarding	5.4
Baseball	1.8
Cheerleading	1.5
Wrestling	1.8

Less than 1% of participants were injured in each of the following: field hockey, rugby, bicycling, dancing, horseback riding, track and field, softball, volleyball, diving, gymnastics, swimming, sailing, crew, squash, dodge ball, ultimate Frisbee, broom ball, skateboarding, and during gym class.

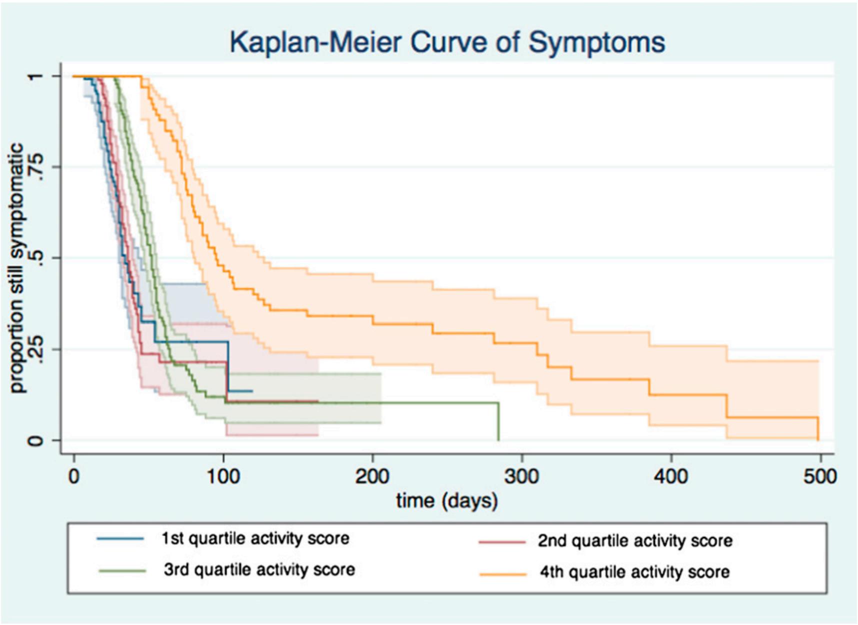

FIGURE 1
Duration of symptoms by quartile of cognitive activity-days. Shaded area represents 95% confidence intervals for the curve.

only total score on the PCSS at the initial visit and cognitive activity-days were independently associated with duration of symptoms (Table 3). Gender, age, loss of consciousness, amnesia, and number of previous concussions were not independently associated with time to symptom resolution (Table 3).

DISCUSSION

By showing that those engaged in the highest levels of cognitive activity had the longest times to symptom resolution, our study supports the use of cognitive rest and contributes prospective data to the current consensus opinion that limiting extensive cognitive activity reduces duration of concussion symptoms.

The concept of cognitive rest was introduced at the Second International Conference on Concussion in Sport, which was held in Prague in 2004. The summary and agreement statement from that meeting recognized cognitive rest as "a need to limit exertion with activities of daily living and to limit scholastic activities while symptomatic," further stating, "During this period of recovery in the first few days after an injury, it is important to emphasize to the athlete that physical and cognitive rest is required. Activities that require concentration and attention may exacerbate the symptoms and as a result delay recovery."[10] In subsequent meetings, the concept was reinforced, with physical and cognitive rest being described as "the cornerstone of concussion management."[11] Although it is difficult to quantify, cognitive rest entails limiting activities that require attention and concentration, such as reading, text messaging, video game playing, working online, and performing schoolwork.[12,13]

One of the most commonly cited hypotheses regarding the pathophysiology of concussion postulates that shear forces experienced at the time of injury lead to ionic fluxes, the indiscriminant releases of excitatory neurotransmitters, and a spreading depression-like phenomenon.[14–18] Adenosine triphosphate (ATP) is required to restore homeostasis, but there is decreased cerebral blood flow after injury.[19–21] This mismatch between the increased demand for ATP and decreased supply of ATP is thought to result in prolonged concussion symptoms. One of the reasons for instituting cognitive rest is to conserve the limited ATP supplies for injury recovery, as opposed to using ATP for intellectual tasks.[22] Despite becoming standard therapy for concussion, until now there have been scant published data showing the benefits of cognitive rest on recovery from concussion. Our findings contrast with those of Gibson et al, most likely because our current study prospectively measured cognitive activity level as opposed to retrospectively assessing whether the recommendation for cognitive rest was given.[8] Our findings support the work of Majerske et al and Moser et al, as well as the expert opinion of many clinicians involved in the assessment and management of sport-related concussion.[5–7] Furthermore, our study adds empirical support to the practice of putting academic accommodations in place

TABLE 3 Results of Multivariate Cox Regression Model of Prolonged Recovery

Variable	Hazard Ratio	SE	95% CI
Gender	1.2935	0.1857	0.9762–1.7139
Age	0.9834	0.0254	0.9348–1.0345
Loss of consciousness	1.1148	0.1960	0.7899–1.5734
Number of previous concussions	1.0330	0.0687	0.9067–1.1769
Total score on initial PCSS[a]	0.9797	0.0030	0.9738–0.9856
Amnesia	1.2273	0.1773	0.9245–1.6292
Cognitive activity-days[a]	0.9942	0.0009	0.9924–0.9960

CI, confidence interval.
[a] Independently associated with symptom duration.

for student-athletes suffering from sport-related concussions. Such accommodations allow for relative cognitive rest in the setting of the school year and are an important first step in the management of concussion.[13,22–24] Given our findings, it is likely that academic accommodations can speed the recovery process. It is worth noting, however, that although those in the highest quartile of cognitive activity experienced a substantially longer duration of symptoms, those engaged in the 3 lower quartiles of cognitive activity had similar trajectories of symptom duration (Fig 1). This seems to suggest that while limiting cognitive activity is associated with a shorter duration of symptoms, complete abstinence from cognitive activity may be unnecessary. This is similar to the findings by Majerske et al, who found that those engaging in moderate levels of activity had better outcomes than those engaging in the highest and lowest levels of activity.[7] In addition, the effect of cognitive rest may vary over time, such that cognitive activity has more of an effect on recovery during the earlier phases. Further studies will be needed to determine how the effect of cognitive activity changes over time.

Our findings must be considered in light of several limitations. Patients referred to a designated specialty Sports Concussion Clinic may differ from the general population of concussed athletes, thus limiting the generalizability of our conclusions. Given the small proportion of athletes who had neurocognitive testing at the initial visit, we were unable to assess the predictive effect of neurocognitive testing on duration of symptoms. The scale used in this study has not been previously validated, although it was created by 2 clinician-researchers experienced in concussion management. Furthermore, our results serve as preliminary validation that activity recorded on the scale is associated with duration of symptoms. It is possible that parents may have assisted younger athletes in completing the cognitive activity scale, possibly altering the answers from what the athletes themselves would have reported. Lastly, as opposed to directly measuring cognitive activity, we asked patients to recall their level of cognitive activity. However, we are aware of no current means for accurately measuring cognitive activity. We also follow patients in our clinic fairly frequently, usually every 3 to 6 weeks, and hope this close follow-up led to fairly accurate estimates of cognitive activity.

CONCLUSIONS

Extensive cognitive activity level after concussion is associated with longer symptom duration. These findings support current recommendations for limiting extensive cognitive activity after injury.

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