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Relationship Between Physical Activity Participation and Recovery Outcomes in College-Aged Adults With a Concussion

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Context: Previously, the most common treatment for a concussion was prolonged physical and cognitive rest. Recently, researchers have suggested that earlier physical activity (PA) may be better at promoting recovery. Researchers have not evaluated the relationship between free-living PA (eg, walking) and symptom reporting or recovery duration.

Objective: To assess the relationship between free-living PA participation and 2 recovery outcomes in college-aged adults with a concussion.

Design: Prospective cohort.

Setting: National Collegiate Athletic Association Division I and III universities.

Patients or Other Participants: Thirty-two college-aged adults (68.8% female, age = 19.8 ± 1.4 years) with a concussion.

Main Outcome Measure(s): Participants completed a postconcussion symptom evaluation at visits 1 (<72 hours from concussion) and 2 (8 days later). Between visits, each participant's PA was monitored using an Actigraph GT9X Link PA monitor and expressed as total PA (counts per minute) and percentage of PA time spent in moderate-to-vigorous intensity (%MVPA). Recovery time was the number of days from injury occurrence to medical clearance. With separate hierarchical multiple regressions, we evaluated the relationship between total PA and each recovery variable (visit 2 symptom severity, recovery time). Additionally, with separate exploratory hierarchical multiple regressions, we evaluated the relationship between %MVPA and each recovery variable. Statistical significance was set a priori at $P \leq .05$.

Results: Participants averaged 2446 ± 441 counts per minute and spent 12.1% ± 4.2% of their PA performing MVPA. Participants yielded median (interquartile) symptom severities of 28 (24) and 2 (8) for visit 1 and 2, respectively. Average recovery time was 14.7 ± 7.5 days. Total PA did not significantly contribute to the model for visit 2 symptom severity ($P = .122$) or recovery time ($P = .301$). Similarly, %MVPA had little contribution to the model for visit 2 symptom severity ($P = .358$) or recovery time ($P = .276$).

Conclusions: We suggest that free-living PA may not be enough to reduce symptoms or shorten recovery. Thus, clinicians may need to provide patients with more structured PA protocols mimicking findings from previous researchers.

Key Words: Actigraph, symptoms

Key Points

- During the first week after a concussion, 12% of physical activity completed by college-aged adults was classified as moderate-to-vigorous intensity.
- Free-living physical activity participation during the first week after concussion was not associated with symptom reporting or overall recovery time.

Concussions account for approximately 6% of all injuries in collegiate sports.[1] Individuals with a concussion may experience an array of symptoms, cognitive impairments, and balance deficits, which typically resolve within 2 weeks of injury for adults.[2] However, approximately 15% of individuals experience a protracted recovery lasting longer than 30 days.[3] Factors such as sex,[4] age,[4] and previous health history[5] have all been reported to influence concussion-recovery time. Additionally, several concussion-management techniques have also been found to influence concussion-recovery trajectories.[6–8]

For years, health care providers emphasized prolonged physical rest until patients were completely asymptomatic, regardless of recovery duration.[9] Physical rest is believed to ease discomfort during the acute recovery phase, minimize the excessive energy demands of the brain, and limit the chances of a subsequent head injury.[10,11] Despite these perceived benefits, little research evidence exists supporting the benefits of rest beyond the acute recovery phase. Furthermore, prolonged periods of rest may be associated with delays in symptom resolution and a longer recovery time.[6,12] Specifically, Thomas et al[6] found that extending rest periods by an extra 3 days delayed symptom resolution for 50% of adolescent patients. As a result, researchers have begun investigating more proactive strategies, such as incorporating physical activity (PA) earlier in concussion recovery.

Physical activity has previously been shown to influence various aspects of cognition and symptom reporting for chronic brain disorders.[13,14] With these findings, researchers[13,14] suggested that PA may also have some use in treating other conditions of the brain, such as a concussion. When implementing a PA protocol early in recovery, investigators[8,15] found that children with a concussion recovered 3 to 15 days faster and reported fewer concussion symptoms than those who were instructed to strictly rest. The exercise intensity for these participants was 80% of the heart rate at which symptoms were exacerbated.[8,15] This emphasis on heart rate may suggest that PA intensity is a crucial factor in concussion PA protocols. It should be noted that most concussion PA research includes treadmill- or stationary bike-based protocols, which require direct clinical supervision.[7,8,15] Unfortunately, these types of interventions are not clinically feasible for all health care professionals due to a lack of resources, training, and time. Thus, identifying a more clinically feasible approach, such as increasing daily free-living PA, may be sufficient for improving concussion-recovery outcomes.

Researchers[16,17] have quantified free-living PA participation (eg, walking) in youth athletes after a concussion. In one investigation, an immediate reduction occurred in the average daily step counts of concussed high school and collegiate athletes compared with healthy control individuals (6663 versus 11 148 steps, respectively, per day).[17] Despite this initial decline, athletes with a concussion slowly returned to similar activity levels as their healthy counterparts over the course of their recovery.[17] In another study,[16] more postconcussion PA was associated with significantly fewer vestibular symptoms after injury. These preliminary findings suggest a possible association between free-living PA participation and aspects of concussion recovery. However, this possible link has only been evaluated in youth athletes via a single vestibular assessment. Further research is needed to evaluate this concept in an older population (ie, college-aged adults), as well as to evaluate the influence of this type of PA on other indicators of concussion recovery (ie, symptom reporting and recovery time). Therefore, the purpose of our study was to assess the relationship between free-living PA participation and 2 recovery outcomes in college-aged adults with a concussion. We hypothesized that adults with greater PA participation would report fewer concussion symptoms and recover faster than adults with less PA participation.

METHODS

Design and Participants

A prospective cohort study design was used to assess the relationship between PA participation and indicators of recovery after a concussion. The current study was approved by the institutional review board before data collection. Participants were recruited from a National Collegiate Athletic Association (NCAA) Division I university and an NCAA Division III university. Participants were included in the study if they were between the ages of 18 and 24 years, diagnosed with a concussion, and completed their first visit within 72 hours of their concussion. Participants were excluded if they had an additional diagnosed concussion within the past 6 months, were currently taking any central nervous system–active prescription medication, had a history of moderate or severe traumatic brain injury, or had a history of brain surgery. Participants with a current cardiovascular disorder or lower extremity injury were also excluded due to the potential effects on PA participation.

Operational Definitions

Concussion. All concussion diagnoses were made by a health care professional (eg, MD or DO) using the operational concussion definition provided by the 5th International Concussion in Sport Group.[2] The International Concussion in Sport Group defines a *concussion* as a complex pathophysiological process affecting the brain that is induced by biomechanical forces.[2] Additionally, 2 criteria were used by professionals when diagnosing individuals with a concussion. The first criterion was an observed or reported mechanism of injury. The second criterion was the presence of at least 1 of the following: (1) on-field signs (eg, disorientation or confusion, loss of consciousness, balance difficulties, or amnesia), (2) symptoms (dizziness, nausea, or headache), or (3) any impairment on sideline assessments (eg, SCAT5).

Recovery Time. *Participant recovery time* was classified as the number of days from injury occurrence to clearance for full unrestricted activity by a health care provider (MD, DO, or nurse practitioner). Medical clearance was determined with a multifaceted approach but was ultimately based on the health care provider's discretion.

Instrumentation

Postconcussion Symptom Evaluation. The Postconcussion Symptom Scale consists of 22 common postconcussion symptoms (eg, headache, dizziness, and difficulty concentrating) on a 7-point Likert scale (0 [*none*] to 6 [*severe*]). Participants rated these symptoms based on how they felt at the time of their visit. Postconcussion symptom total was the total number of symptoms endorsed out of 22, and symptom severity was calculated by adding the Likert-scale scores of all reported symptoms, for a maximum score of 132. This symptom scale has been shown to be a valid tool when assessing individuals for a concussion.[18]

Actigraph GT9X Link PA Monitor. Participants were asked to wear a GT9X Link PA monitor (Actigraph Corp) on their nondominant wrist between visits 1 and 2. Participants were instructed to remove the monitor only during water activities (eg, bathing and swimming) or any activity that might significantly damage the device. Data acquired from the monitors were collected in raw form with a sample frequency of 30 Hz. The data were processed in 60-second epochs using ActiLife Software (Actigraph Corp). Participants were required to wear the monitor for 7 consecutive days and a minimum of 8 hours per day for the data to be considered valid and usable. Monitor wear time was validated using the algorithm by Choi et al.[19] Actigraph PA monitors have previously been shown to be valid and reliable for measuring PA under free-living conditions in young and active adults.[20] Additionally, the nondominant wrist location was chosen to increase patient compliance, as this anatomical placement was most preferred by patients in previous research and matched the procedures for the moderate-to-vigorous physical activity (MVPA) cut points.[21,22] To determine the percentage of PA time spent in MVPA (%MVPA), wrist-specific cut points were used to classify intensity as either light PA or MVPA.[23]

Daily Questionnaire. Participants completed a daily online questionnaire between the first 2 visits. The questionnaire used the Qualtrics platform and took no longer than 3 minutes to complete. The questionnaire asked participants to self-report their total time (in minutes) spent on homework and in class each day. Total cognitive activity was evaluated for its potential effect on symptom reporting and recovery time.

Procedures

Participants with a diagnosed concussion completed their first visit within 72 hours of sustaining their injury. During the first visit, participants provided informed consent, supplied personal and injury demographic information, completed the postconcussion symptom scale (PCSS), and were given an Actigraph GT9X Link PA monitor. Participants were instructed to wear the device as described in the Instrumentation section. Physical activity was monitored starting no earlier than 48 hours and no later than 72 hours after the participant sustained a concussion. This timing was due to physical rest being recommended for the first 48 hours after injury by a current consensus statement.[2]

Between visits 1 and 2, participants completed the Qualtrics questionnaire daily at 8:00 PM based on their current day. They then returned for their second visit at 8 days (± 1 day) after visit 1 and again completed the PCSS. After visit 2, participants returned their PA monitor to researchers. They continued to be managed by their respective health care providers until they received full, unrestricted medical clearance.

Data Analysis

Participants not meeting monitor wear-time requirements (7 days, minimum of 8 hours per day) or Choi et al[19] validation recommendations were removed before we conducted an analysis. Descriptive statistics were calculated for demographic information, PA participation, and concussion-recovery outcomes (ie, symptom reporting and recovery time). A Mann-Whitney U analysis and an independent-samples t test were used to identify any sex differences for concussion-recovery indicators and PA participation, respectively.

Separate hierarchical multiple regression analyses were used to assess the relationship between total PA (counts per minute) and indicators of concussion recovery (visit 2 symptom severity and recovery time) while accounting for visit 1 symptom severity.[4,24] In addition, participant sex was entered into the symptom-reporting model to account for its influence on visit 2 symptom severity.[25,26]

Separate exploratory hierarchical multiple regression analyses were completed to assess the relationship between PA intensity (%MVPA) and the indicators of concussion recovery (visit 2 symptom severity and recovery time). As in the previous analyses, visit 1 symptom severity was entered into the models to account for its influence on visit 2 symptom severity and recovery time. Participant sex was only entered into the symptom-reporting model due to its previously noted influence on symptom reporting.[25,26] All statistical analyses were conducted using SPSS (version 24.0; IBM Corp). An a priori α level was set at $P = .05$ for all analyses.

Table 1. Participant Demographics

Demographic Variable	Values, n (%)[a]
Age, mean ± SD, y	19.8 ± 1.4
Sex	
Male	10 (31.3)
Female	22 (68.8)
Academic class	
Freshman	9 (28.1)
Sophomore	7 (21.9)
Junior	8 (25.0)
Senior	7 (21.9)
Graduate student	1 (3.1)
Medical diagnoses	
ADHD/ADD	5 (15.6)
Depression/anxiety	7 (21.9)
Previous concussion	17 (53.1)

Abbreviations: ADD, attention-deficit disorder; ADHD, attention-deficit hyperactivity disorder.

[a] Except where indicated otherwise.

RESULTS

Demographic Information

A total of 44 college-aged adults with a concussion were enrolled in the current study. Of the enrolled participants, 1 person (2.2%) was later excluded due to not reaching full medical clearance within the study timeframe. Additionally, 10 participants (22.7%) were removed for not meeting study requirements for monitor wear time (7 days, minimum of 8 hours per day) or Choi et al[19] validation requirements for Actigraph wear time. Finally, 1 participant (2.2%) was removed from analysis due to the symptom-reporting (visit 1 and 2 severity) and recovery-time results being classified as outlier values relative to the distribution among our sample (z score of >3.0).

Thirty-two participants (68.8% female, age = 19.8 ± 1.4 years) were included in our final analyses. Table 1 provides additional participant demographic information.

Concussion Outcomes

Females reported greater symptom severity than males at visit 2 ($U = 51.00$, $P = .014$). In addition, a significant relationship was found between visit 1 symptom severity and visit 2 symptom severity ($r_s = 0.354$, $P = .044$). Table 2 gives symptom-reporting results, whereas Table 3 shows concussion-recovery time for all participants. It should be noted that total minutes spent in class or studying had no effect on symptom reporting ($r_s = 0.347$, $P = .065$) or recovery time ($r_s = 0.301$, $P = .112$).

Physical Activity

Recording of a participant's PA started an average of 54.5 ± 8.8 hours after the injury was sustained. On average, participants recorded 2446 ± 441 counts per minute and spent 12.1% ± 4.2% of their time in MVPA.

Table 2. Participants' Symptom Totals and Severity Reported at Visits 1 and 2 By Sex and Medical History

Variable	Visit 1				Visit 2			
	Symptom Total		Symptom Severity		Symptom Total		Symptom Severity	
	Mean ± SD	Median [IQR]	Mean ± SD	Median [IQR]	Mean ± SD	Median [IQR]	Mean ± SD	Median [IQR]
Sex								
Male	11.8 ± 5.5	12.5 [9]	23.2 ± 13.3	25.0 [24]	0.8 ± 1.3	0.0 [2]	1.0 ± 1.7	0.0 [3]
Female	13.9 ± 4.0	13.5 [6]	36.2 ± 21.4	30.5 [40]	4.8 ± 5.3	3.0 [8]	9.6 ± 13.6	3.0 [11]
Total	13.3 ± 4.5	13.0 [7]	32.2 ± 20.0	28.0 [24]	3.5 ± 4.8	1.5 [6]	6.9 ± 12.0	1.5 [8]
ADHD/ADD								
No	13.3 ± 4.6	13.0 [6]	31.9 ± 20.6	28.0 [24]	3.4 ± 4.7	1.0 [6]	6.5 ± 11.9	1.0 [7]
Yes	12.8 ± 4.3	14.0 [8]	33.4 ± 17.9	26.0 [32]	4.2 ± 5.8	3.0 [9]	9.0 ± 13.9	3.0 [21]
Depression/anxiety								
No	13.0 ± 4.7	13.0 [7]	32.1 ± 19.8	28.0 [26]	3.4 ± 4.4	1.0 [6]	6.8 ± 11.6	1.0 [9]
Yes	14.0 ± 4.1	14.0 [5]	32.4 ± 22.4	25.0 [14]	4.1 ± 6.2	3.0 [2]	7.3 ± 14.1	3.0 [3]
Previous concussion								
No	13.3 ± 3.4	13 [5]	33.4 ± 20.2	28.0 [22]	5.4 ± 5.9	3.0 [9]	10.7 ± 15.1	4 [13]
Yes	13.2 ± 5.4	14.0 [8]	31.1 ± 20.4	28.0 [24]	1.9 ± 2.8	1.0 [3]	3.6 ± 7.3	1 [4]

Abbreviations: ADD, attention-deficit disorder; ADHD, attention-deficit/hyperactivity disorder.

Detailed PA results for all participants can be found in Table 4.

Predictors of Recovery

When we evaluated the relationship between total PA and visit 2 symptom severity, participant sex and visit 1 symptom severity were entered into the model first. Step 1 yielded an overall significant model ($F_{2,29}$ = 7.57, P = .002), accounting for 34.3% of the variance (R^2 = 0.343). After the total PA was entered, the model remained significant ($F_{3,28}$ = 6.16, P = .002) and accounted for 39.8% of the variance (R^2 = 0.398; R^2 change = 0.055). Visit 1 symptom severity was a significant contributor to the final model (B = 0.315; 95% CI = 0.125, 0.504; P = .002), whereas participant sex (B = 5.58; 95% CI = –2.53, 13.69; P = .170) and total PA (B = –0.006; 95% CI = –0.015, 0.002; P = .122) were not. No significant findings were present when we evaluated the relationship between total PA and recovery time while accounting for visit 1 symptom severity (step 1: $F_{1,30}$ = 0.12, P = .732, R^2 = 0.004; step 2: $F_{2,29}$ = 0.616, P = .547, R^2 = 0.041; R^2 change = 0.037).

We used an exploratory analysis to evaluate the relationship between %MVPA and visit 2 symptom severity. During this analysis, participant sex and visit 1 symptom severity were entered into the model first, yielding an overall significant model ($F_{2,29}$ = 7.57, P = .002) that accounted for 34.3% of the variance (R^2 = 0.343). After adding %MVPA, we found that the model remained significant ($F_{3,28}$ = 5.32, P = .005) and accounted for 36.3% of the variance (R^2 = 0.363; R^2 change = 0.020). However, %MVPA (B = –0.404; 95% CI = –1.29, 0.481; P = .358) and participant sex (B = 4.72; 95% CI = –3.35, 12.97; P = .251) did not significantly contribute to the model. Visit 1 symptom severity was the only significant contributor to the model (B = 0.313; 95% CI = 0.117, 0.510; P = .003). Similarly, no significant findings were found between %MVPA and recovery time while accounting for visit 1 symptom severity (step 1: $F_{1,30}$ = 0.12, P = .732, R^2 = 0.004; step 2: $F_{2,29}$ = 0.677, P = .516, R^2 = 0.045; R^2 change = 0.041).

Table 3. Participant Concussion Recovery Time, d

Variable	Mean ± SD	Median [Interquartile Range]
Sex		
Male	12.4 ± 6.7	10.5 [4]
Female	15.7 ± 7.7	14.0 [9]
Total	14.7 ± 7.5	11.5 [9]
ADHD/ADD		
No	15.2 ± 7.9	12.0 [9]
Yes	12.0 ± 3.7	11.0 [7]
Depression/anxiety		
No	15.1 ± 8.1	12.0 [10]
Yes	13.1 ± 4.5	11.0 [6]
Previous concussion		
No	16.1 ± 8.6	13.0 [6]
Yes	13.5 ± 6.4	11.0 [10]

Abbreviations: ADD, attention-deficit disorder; ADHD, attention-deficit/hyperactivity disorder.

DISCUSSION

The purpose of our study was to evaluate the relationship between PA and symptom reporting and recovery time in college-aged adults with a concussion. The sample of adult

Table 4. Physical Activity Results

Variable	Mean ± SD	Median [Interquartile Range]	Minimum–Maximum
% PA in light activity			
Males	89.3 ± 1.9	89.0 [3.0]	86.8–92.5
Females	87.7 ± 4.3	89.0 [4.3]	77.7–95.5
Total	88.2 ± 3.7	88.6 [5.3]	77.7–95.5
% PA in MVPA			
Males	10.7 ± 1.9	11.0 [3.0]	7.5–13.3
Females	12.3 ± 4.3	11.0 [6.3]	4.5–22.3
Total	11.8 ± 3.7	11.4 [5.3]	4.5–22.3
Counts per minute			
Males	2330.0 ± 333.7	2287.8 [359.9]	1861.1–3023.1
Females	2498.4 ± 480.3	2430.4 [744.6]	1698.7–3637.1
Total	2445.7 ± 441.4	2348.2 [648.4]	1698.7–3637.1
Steps per minute			
Males	13.4 ± 1.8	13.3 [2.7]	11.2–17.2
Females	13.5 ± 2.3	13.8 [3.4]	9.0–18.6
Total	13.5 ± 2.2	13.6 [2.9]	9.0–18.6

Abbreviations: MVPA, moderate-to-vigorous physical activity; PA, physical activity.

participants recorded similar PA results to those found in adolescents with a concussion (2446 versus 2550 counts per minute, respectively).[16] These similar findings suggest that free-living PA may be relatively consistent among different age groups during the first week after concussion. However, unlike Sufrinko et al,[16] we identified no significant changes (R^2 change = 0.020–0.055) to our regression model when adding the PA variables (total PA and %MVPA), which may have been due to age-related recovery differences or the recovery variables assessed (symptom severity versus vestibular symptoms). Rather, in the current study, the only significant contributing factor to either model was visit 1 symptom reporting. In addition, our exploratory analyses revealed no significant models for concussion-recovery time. Considering the lack of statistically significant findings, our results suggest that simply modifying free-living PA may not be enough to affect recovery after a concussion.

We also explored the relationship between %MVPA measured by an Actigraph monitor and concussion recovery. While pursuing free-living PA, participants spent 88% of their time performing light activities and only 12% performing MVPA. Given that participants spent most of their time in light PA, light intensity may not be sufficient to induce a therapeutic response after concussion. This intensity insufficiency was also noted by Varner et al,[27] who found no significant changes in symptoms when implementing a 30-minute light PA regiment after a mild traumatic brain injury. Conversely, other researchers[7,8,15] used a more structured treadmill-based approach in which participants determined their intensity based on symptom exacerbation. Due to the individualized approach in determining PA intensity, it is possible that participants in other studies were engaged in more intense PA than in the current study. Specifically, Leddy et al[7,15] used a 20-minute protocol requiring participants to maintain a heart rate at 80% of their pre-established symptom-provoking threshold. Thus, they may have been able to tolerate PA intensity at moderate-to-vigorous levels. After using this protocol, recovery-time improvements were seen in these participants compared with those who did not receive the treatment.[15] However, our exploratory analysis found no significant relationship between free-living PA intensity (%MVPA) and concussion-recovery time. It is possible that these conflicting results are due to differences in PA intensity. Unfortunately, we were unable to examine vigorous PA alone, as the only existing wrist cut points (ie, those used in this study) do not differentiate between moderate and vigorous PA. Therefore, future authors who evaluate PA after a concussion should monitor and report as many PA (ie, mode, duration, and frequency) and patient (ie, heart rate) details as possible to allow for a comparison between structured and free-living PA. Researchers should also confirm if meeting an intensity or movement threshold (ie, 10 000 steps per day) improves concussion recovery.

Although PA is a promising management technique, another factor may have also influenced our results. A strong social support system has been shown to be a critical component when patients are recovering from a concussion.[28] Specifically, 89% and 78% of individuals relied on family and friends, respectively, for support while recovering from a concussion.[28] Moreover, athletes who reported high-level satisfaction with their support network had fewer anxiety symptoms throughout their concussion recovery.[28] Thus, in our study, it is possible that sedentary participants spent more of their time seeking social support after their injury than engaging in PA. Although current management practices aim to better incorporate PA postinjury, the importance of a strong social support network should not be underestimated.

This study was not without limitations. Although 44 participants were enrolled, 12 were excluded from the final analysis. This exclusion yielded a small sample size of 32 participants, making the results challenging to interpret. The use of counts per minute as a measure of PA also posed a challenge with respect to the generalizability of the findings. In addition, our study lacked a control group of healthy college-aged students, which would have permitted PA comparisons. Another limitation was the inability to account for all external factors that may have influenced symptom reporting or recovery time. Specifically, participants were not asked about social activities or support or specific cognitive activities (eg, screen time) that were performed during the study. As previously mentioned, we were not able to differentiate between moderate and vigorous PA due to a lack of available cut points. Finally, in this pragmatic study, we relied on multiple health care providers for concussion diagnosis and management. We believed it would be unreasonable to ask clinicians to alter their current clinical practice for the study and, thus, participants may have received slightly different standards of care or been subject to different medical clearance criteria.

Although previous researchers identified more structured PA as improving concussion recovery, we found no such relationship in a free-living condition. These results suggest that PA intensity may be a modulating factor for concussion recovery. Future investigators need to directly compare the effects of different PA intensities and modes on concussion recovery. Measuring variable counts per minute is unique to the Actigraph monitor and challenging to directly apply clinically, yet our work may influence the PA mode that should be implemented after concussion. Specifically, when managing patients with a concussion, clinicians may need to provide a specific PA protocol rather than simply advising them to "increase their daily activity." For example, clinicians may recommend a specific treadmill or stationary bike protocol that has been shown to be beneficial after a concussion.[7,15]

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