Acute Physical and Mental Activity Influence on Concussion Recovery

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ABSTRACT

BUCKLEY, T. A., B. A. MUNKASY, K. M. EVANS, and B. CLOUSE. Acute Physical and Mental Activity Influence on Concussion Recovery. *Med. Sci. Sports Exerc.*, Vol. 54, No. 2, pp. 307–312, 2022. **Introduction:** Physical activity (PA) and mental activity (MA) postconcussion has received renewed attention to improve concussion management; however, most protocols start after several days and do not assess the acute window. Therefore, the purpose of this study was to assess PA and MA in the first 48 h postconcussion on the time to symptom-free status and return to play. **Methods:** We recruited 78 NCAA Division I athletes (male, 51.3%; age, 19.6 ± 1.4 yr; height, 173.7 ± 11.5 cm; weight, 80.1 ± 23.2 kg) who were diagnosed with a sports-related concussion. Participants completed a 0–5 PA and MA scale daily until fully cleared for return to participation (mean, 15.1 ± 6.9 d). A quadratic model regression assessed PA and MA over the first 2 d (acute) postconcussion on to time to symptom-free status and return to play. **Results:** The overall model was significant for both time to symptom free (r^2 = 0.27, P = 0.004) and return to play (r^2 = 0.23, P = 0.019). Reported PA was the only significant predictor for time to symptom-free (P = 0.002) and return-to-participation (P = 0.006) day. Reported MA was not associated either outcome. **Conclusions:** The primary finding of this study was that mild to moderate PA acutely postconcussion was associated with reduced time to symptom free and return to participation as opposed to either lower or higher levels of PA. Conversely, acute MA was not associated with recovery outcomes. These results further elucidate the role of postconcussion PA. **Key Words:** COGNITIVE REST, MILD TRAUMATIC BRAIN INJURY, EXERCISE, REHABILITATION

Sports-related concussion is a heterogeneous injury that, in addition to diverse symptoms, adversely affects multiple neurological domains, including cognitive, visual, autonomic, postural control, and mental health (1–6). Acute diagnostic concussion sensitivity has continued to improve in recent years (7); however, evidence-based acute treatment options remain limited (8). Acute concussion management in the 1930s recommended 3 wk of bed rest for head trauma patients, likely encompassing both mild traumatic brain injury and more severe injuries, but by 1942, recommendations to minimize the duration of rest and inactivity were emerging (9). Moving forward, the first Concussion in Sport (CIS) Consensus Statement in 2001 prescribed complete rest and no activity until asymptomatic (10), and the third CIS labeled physical and cognitive rest as the "cornerstone" of concussion management (11) despite "sparse" supporting evidence (12). Currently, both the fifth CIS and the Centers for Disease Control and Prevention continue to recommend an initial period of cognitive and physical rest (24–48 h) before initiating symptom-limiting activities while acknowledging insufficient evidence to support the recommendations (1,13). Optimal timing of initiation, dosage, and mode of activity have not been established (13).

Early concussion management protocols that endorsed "cocoon therapy" (i.e., complete physical and cognitive rest until symptoms resolve [12]) likely were based, in part, on animal studies which showed that the neurometabolic response to exercise may prolong recovery (14–17). These findings were supported by some human studies suggesting that high levels of activity were associated with delayed recovery (18–24); however, these studies typically reported on moderate to vigorous activity and often averaged activity levels across days or weeks. Interestingly, and similarly, strict cognitive and physical rest have also largely not been effective in improving concussion recovery (25–28). Two alternatives have been explored, allowing the individual to maintain limited activities of daily living (ADL) while still restricting moderate to vigorous activity (e.g., workouts and sports) or adding controlled physical exercise to the acute and subacute phase of concussion rehabilitation (25–27,29–36). Limiting the amount of rest to several days and then gradually returning to ADL may be more

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effective than prolonged physical and cognitive rest (21,26–33). The implementation of aerobic exercise, after at least 24–48 h of postconcussion rest, may also be generally effective for reducing symptoms and improving outcomes (23,34–36). Although resuming full physical and cognitive activities immediately postconcussion is contraindicated (8), lower levels of activity within the first 48 h have received limited attention.

Taken together, these studies suggest that too much or too little activity likely is detrimental to recovery and a "sweet spot" of activity likely exists. This was supported by an early study by Majerske et al. (37), who found that mild to moderate activity was associated with the better recovery whereas either very low or very high levels had poorer outcomes. These findings support the emerging approach of 24–48 h of rest followed by resumption of subsymptomatic physical activity (PA) and mental activity (MA), which is consistent with the current fifth CIS (1). However, the individual's activity levels within the first 24–48 h may also play a key role in recovery but has received limited attention. One study found that maintaining ADL, as opposed to strict rest, within this 48-h window was associated with shorter time to symptom resolution, but there were no measures of activity reported in the study (25).

The appropriate balance between rest and activity acutely postconcussion remains to be elucidated, and the initial 48 h may be an added treatment window for sports medicine clinicians. Therefore, the purpose of this study was to assess PA and MA in the first 48 h postconcussion on the time to symptom-free status and return to play. Consistent with the "sweet spot" previously proposed, we hypothesized that both the lowest and the highest levels of PA and CA would have the worst outcomes and a mild to moderate level of PA and CA would have shortest time to recovery.

METHODS

Participants. We recruited 78 National Collegiate Athletic Association Division I student-athletes and cheerleaders over 4 yr as part of a prospective study on concussion recovery (Table 1). The inclusion criteria were participants experiencing a sports-related concussion, which resolved within 2 months and completed the institutions concussion return to participation (RTP) protocol. Potential participants were excluded if they suffered a serious comorbidity (e.g., fracture) at the time of the concussion, delayed reporting the concussion beyond the conclusion of the current game/practice (38), experienced a subsequent injury before RTP, or missed data points in the study. All concussions were initially identified by certified athletic trainers and confirmed by a licensed physician consistent with the contemporary consensus statement (11,12). There were 112 potential cases during this period, but 19 were missing required data (1 withdrew during the study period), 11 were removed for delayed concussion reporting, 2 were removed for prolonged recovery (>2 months), 1 was removed for a subsequent injury before RTP, and 1 was removed for a substantial comorbidity at the time of the concussion. All participants provided written and oral informed consent before participation as approved by the university's institutional review board.

TABLE 1. Participant demographics and characteristics.

Participants	
Sex	51.3% male (40/78)
Age (yr)	19.6 ± 1.4 (range, 18–23)
Height (cm)	173.7 ± 11.5 (range, 141–201)
Weight (kg)	80.1 + 23.2 (range, 44.2–135.9)
Previous concussion history	Yes = 53.8% (42/78), number = 0.8 ± 1.0 (range, 0–4)
Loss of consciousness	6.4% (5/78)
Posttraumatic amnesia	26.9% (21/78)
Time to symptom-free status	6.5 + 5.4 d (range, 1–29)
Time to RTP	15.1 + 6.9 d (range, 7–48)
GSC score (day 1)	25.4 ± 21.2 (range, 1–108)
GSC score (mean days 1–3)	18.9 ± 17.0 (range, 0–96)
Sports	Football: 39.7% (31/78)
	Cheerleading: 20.5% (16/78)
	Women's soccer: 11.5% (9/78)
	Women's basketball: 11.5% (9/78)
	Men's soccer: 3.8% (3/78)
	Men's basketball: 3.8% (3/78)
	Swim/dive: 2.6% (2/78)
	Track and field: 1.3% (1/78)
	Volleyball: 1.3% (1/78)
	Softball: 1.3% (1/78)
	Baseball: 1.3% (1/78)
	Tennis: 1.3% (1/78)

Instrumentation. The participants completed the contemporary Sport Concussion Assessment Tool (SCAT) during a baseline/preparticipation assessment, which consisted of 1) Graded Symptom Checklist (GSC), 2) Balance Error Scoring System (BESS), and 3) Standard Assessment of Concussion (SAC) as well as the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) computerized neurocognitive assessment. This assessment battery is commonly used by athletic trainers (39,40) and sports medicine physicians and has been extensively described in the literature (41,42).

Procedures. After a sports-related concussion, participants were assessed on the SCAT daily and ImPACT approximately twice a week until baseline values were achieved. To be considered symptom free, the participants had to score a "0" on the GSC specific to concussion-related symptoms as per physician clinical protocol despite ongoing debate on defining "asymptomatic/symptom free" (43). The RTP protocol was consistent with the contemporary consensus guidelines and required the individual to be symptom free, "pass" the BESS, SAC, and ImPACT with scores equal to or better than their baseline (11,12). The participants then completed a sport-specific six-step progressive return to activity protocol (11,12). If a participant was symptom free and had symptoms reemerge, then the symptom-free date was revised to the later date.

The two predictors in this study were the self-reported PA and MA. The scales were completed daily beginning the day after the concussion. The two scales were based on the scales of postconcussion activity of both Brown et al. (19) and Majerske et al. (37), but herein the scales were split into PA and MA independently. Both scales were 0–5, with "0" representing minimal activity and "5" representing full unrestricted activity (Table 2). Participants completed the scale via an interview with a member of the research staff and were instructed to rate their activity based on the previous 24 h and indicate what

TABLE 2. Postconcussion activity scale.

Postconcussion Activity Scale
During the last 24 h, how physically active were you? ________
0. No physical activity at all, minimal walking only as needed
1. Walking around casually
2. Light activity at home/residence hall
3. Moderate activity and/or light sports activity
4. Partial practice or light to moderate sports activity
5. Full practice or game (what you would normally be doing if not for the concussion)
During the last 24 h, how mentally active were you? ________
0. Did not attend classes, no homework. No TV, videogames, electronics usage
1. Did not attend classes, no homework, used some TV, videogames, or electronics
2. Attended some classes or did some homework or moderate/heavy electronics
3. Attended some classes and did some homework
4. Attended classes and did homework, but still less than normal
5. Full school activity (what you would normally be doing if not for the concussion)

was their most physically or mentally active events. If the participant was uncertain about the rating, the research staff member discussed their activity with participant to identify the most appropriate selection, but this was a rare occurrence. Participants were frequently reminded that their responses were not shared with the clinical staff and noncompliance with the prescribed recommendations was occasionally acknowledged to the research staff.

Data and statistical analysis. As the purpose of this study was to assess the effect of PA and MA acutely postconcussion on recovery characteristics, the mean values over the first 2 d (48 h) postconcussion were calculated for both the PA and the MA scales. The outcome measures were the number of days until symptom free and days until full RTP. A paired sample *t*-test was used to compare PA and MA activity between day 1 and day 2, with Cohen's *d* effect sizes calculated for significant differences. Because acute symptom burden could influence activity level, a Pearson correlation was performed to investigate the relationship between symptom burden and PA and MA.

A linear regression was used to assess days to Symptom Free and RTP with PA and MA scales as predictors while controlling for sex (male/female), concussion history (yes/no), number of previous concussions, signs of concussion (e.g., LOC, PTA), GSC score on day 1 postconcussion, and mean GSC score over the first 2 d as each of these predictors has been associated with delayed recovery (33,44,45). Because we hypothesized that both a low and a high level of activity would be associated with a worse outcome, a quadratic term was included the model.

RESULTS

Concussion characteristics, initial symptom burden, and the duration of time to asymptomatic and RTP are provided in Table 1.

PA and MA. The participants' self-reported 48-h PA was 1.8 ± 1.1 (range, 0–5; mode, 1.0), and there was no difference between PA on day 1 and day 2 (day 1, 1.7 ± 1.4; day 2, 1.9 ± 1.1; P = 0.608). The participants' self-reported 48-h MA was 2.7 ± 1.4 (range, 0–5; mode, 1.0), and there was a significant increase in MA between day 1 and day 2 (day 1, 2.1 ± 1.6; day 2, 3.3 ± 1.5; P < 0.001; d = 0.77). There was no relationship between acute symptom burden and either early PA (r = 0.17, P = 0.14) or MA (r = 0.01, P = 0.89).

The quadratic regression was significant for both time to symptom free (r^2 = 0.27, P = 0.004) and RTP (r^2 = 0.23, P = 0.019) (Figs. 1 and 2). Reported early PA was the only significant predictor for symptom-free day (P = 0.002, β = 0.353) and RTP day (P = 0.006, β = 0.332). Reported early MA did not predict time to symptom free (β = −0.160, P = 0.155) or RTP (β = −0.152, P = 0.188) (Table 3).

DISCUSSION

There is emerging evidence that PA, not rest, is an effective postconcussion treatment after the acute phase of recovery; however, the effect of PA and MA during the acute phase of recovery (<48 h) is not well established. The primary finding of this study was that mild to moderate PA, but not MA, was associated with shorter times to self-reporting asymptomatic and RTP while controlling for common determinants of concussion recovery. Interestingly, recovery timelines were not affected by any level of MA. These results suggest that acute mild to moderate PA may not be detrimental to concussion recovery.

Clinical concussion management has progressed over the years from complete rest (i.e., "cocoon therapy") to rest till symptom free, and the current recommendations call for 2 d of rest before initiating activity (1,10,11). The results of this study suggest that mild to moderate PA in the first 2 d postconcussion resulted in quicker recovery as measured by time to self-report symptom free and RTP. This finding builds on an earlier study which showed that switching from limited ADL to complete rest resulted in delayed symptom recovery

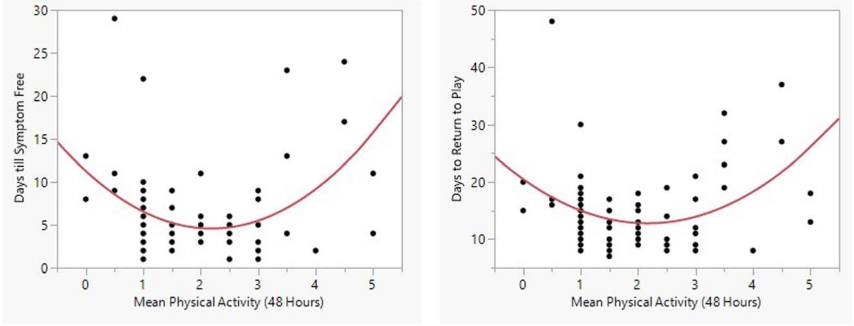

FIGURE 1—Relationship between physical activity and recovery. The quadratic model was significant for both time to symptom free (r^2 = 0.27, P = 0.004) and return to play (r^2 = 0.23, P = 0.019) when controlling for relevant covariates.

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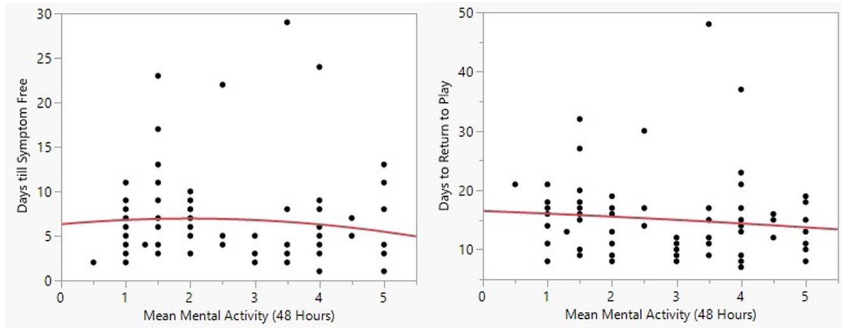

FIGURE 2—Relationship between MA and recovery. The quadratic model was not significant for either the time to symptom free ($r^2 = 0.16$, $P = 0.155$) or return to play ($r^2 = 0.14$, $P = 0.204$) when controlling for relevant covariates.

time in collegiate athletes (25). It is important to note that the result herein controlled for common recovery confounders, including symptom burden within the first 48 h, which is typically the strongest predictor of concussion recovery (44), so it is unlikely that the higher activity levels resulted solely from lower acute symptom burdens.

It was surprising that MA was not associated with either outcome, which suggests that self-reported/perceived high levels of MA acutely postconcussion did not influence outcomes (Fig. 2). Further, the self-reported high-level MA (e.g., 4–5) participants had very similar outcomes to both the low and the moderate MA participants. This finding stands in contrast to two previous studies, which found that MA restrictions were associated with slower recovery; however, these studies cross wide age ranges (8–23), which could explain the different findings (19,27). This result could be biased by high achieving academic students attending class and completing academic assignments, in noncompliance with the concussion protocol, to maintain their academic standing. Nonetheless, this is an area that warrants further exploration with more detailed MA outcome measures, including electronics usage (e.g., time of social media, text messages sent/received, etc.), consideration of the academic rigor of the student's schedule (e.g., multiple laboratory science courses on the same day, mid-term week, etc.), and their perceived academic stress.

There are several possible mechanisms to explain why mild to moderate PA acutely postconcussion resulted in better outcomes. Physiologically, animal studies suggest that voluntary exercise increases brain derived neurotrophic factor and that concussed rodents appropriately self-regulated PA to maximize recovery (17,46). It is plausible that the participants herein also self-regulated to a preferred activity level, which did not exacerbate symptoms but was well above resting levels. Further, exercise started 1 d postconcussion showed improved neurological function, including improved motor control and cognition in rodents (46). Thus, neurophysiological response to activity may explain the improved outcomes. Alternatively, concussions are known to adversely affect mental health (5), and removal from team activities and classes may be associated with what Thomas et al. (27) described as a "situational depression." This could be particularly relevant in concussion recovery as concussions are often termed an "invisible injury." Athletes have been reported being questioned on the legitimacy of their injury (47,48), which, in conjunction with removal from team activities, could adversely affect recovery. Although this prospective observational study was not mechanistic in nature, future studies should investigate the underlying neurophysiological and mental health determinants of how activity influences concussion recovery.

The participants in this study self-reported their PA and MA daily to the research staff independent of the clinical staff, and the participants were informed that the information was not shared; thus, although there is high likelihood that participants were being honest in their responses, dishonesty cannot be ruled out. The research team was not blinded to the participants' recovery status during the project, which could have introduced a reporting bias into the results. There was a single participant with prolonged symptoms (symptom free = 29 d), but this individual was still included as postconcussion syndrome is typically defined at symptoms persisting for at least 30 d or more. An exploratory analysis removing this individual did not affect the overall results of the study. It is important to note that several participants had elevated PA and MA levels (4 and 5) acutely postconcussion, and these were all

TABLE 3. Binary logistic regression outcomes.

	Symptom-Free Day			Return to Play Day		
	P	Beta Coefficient	95% CI	*P*	Beta Coefficient	95% CI
Sex	0.054	−0.211	−1.96 to 0.04	0.450	−0.317	−7.39 to 1.35
Concussion history	0.053	−0.331	−7.01 to 0.04	0.156	−0.246	−8.10 to 1.33
Concussion number	0.072	−0.402	−0.32 to 3.98	0.141	0.260	−0.62 to 4.23
GSC scores (day 1)	0.844	0.046	−0.11 to 0.13	0.657	0.446	−0.13 to 0.20
GSC scores (mean)	0.318	0.235	−0.08 to 0.23	0.687	0.405	−0.16 to 0.25
Signs of concussion	0.138	−0.167	−1.41 to 0.20	0.191	−1.321	−1.78 to 0.36
PA	0.002*	0.353	0.12 to 0.57	0.006*	0.332	0.13 to 0.71
MA	0.155	−0.160	−0.26 to 0.04	0.188	−0.152	−0.33 to 0.07

noncompliant with protocols because of a variety of reasons, including not believing they had a concussion, misunderstanding exercise restrictions, fear of falling behind academically, or intentional noncompliance. Not surprisingly, and consistent with previous studies (18–21), these participants generally had longer duration of symptoms and slower time to RTP. Future studies should implement more precise measures of actual and perceived PA and MA to overcome the limitation of a single rating for an entire day based on the participant's self-perception. In some cases, the clinicians performed the GSC with the athlete, and the research team only had access to the total score (total number of symptoms and symptom burden); thus, assessment of individual symptoms (e.g., dizziness, difficulty concentrating, etc.) could not be performed and symptom reporting can be confounded by numerous considerations (49,50). All participants herein were medically managed by the same athletic training and team physician staff using the same concussion management protocol; however, individual management practices and participant experiences/expectations could influence the outcomes of the study. Although there was a close breakdown by sex, these results are limited to collegiate student-athletes, and adolescents may respond differently. In particular, the academic differences between secondary school and college suggest that a separate study of high school athletes should be performed. Although the analysis controlled for many common confounders to concussion recovery, larger sample sizes would allow a thorough statistical analysis to investigate the interaction between activity and sex, team, concussion history, concussion severity, specific symptoms or symptom clusters, mental health measures, and other factors that could influence recovery. Finally, as concussion is a heterogeneous injury, there is likely not a single postinjury protocol that will be "one size fits all," and individual medical management will remain critical to successful patient treatment and outcomes.

CONCLUSIONS

Current recommendations suggest that mild to moderate levels of PA within the first week postconcussion reduces symptoms (46), and the results of this study expand these previous findings to suggest that mild PA within the first 48 h reduced time to both symptom free and RTP. Conversely, acute MA was not associated with either outcome. Future studies should use more sensitive assessment techniques to assess activity within the acute postconcussion phase to help facilitate concussion recovery.

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The authors declare no conflict of interest.

The results of this study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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