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Exercise in the First Week Following Concussion Among Collegiate Athletes: Preliminary Findings

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Abstract

Objective: Our purpose was to examine the association between exercise after concussion with symptom severity, postural control, and time to symptom-resolution.

Design: Longitudinal cohort

Methods: Collegiate athletes (n=72; age=20.2±1.3 years; 46% female) with concussion completed a symptom questionnaire at initial (0.6±0.8 days post-injury) and follow-up (2.9±1.4 days post-injury) evaluations, and a postural control assessment at follow-up. Participants were grouped into those who exercised in between the time of injury and the follow-up evaluation and those who did not. Decisions regarding post-concussion exercise were made by a sports medicine team consisting of a single team physician and athletic trainers.

Results: Thirteen athletes were not included in the current study, resulting in an 85% response rate. Thirteen of the athletes who completed the study exercised between evaluations (18%). There was no symptom resolution time difference between groups (median=13 [IQR=7-18] days vs. 13 [7-23] days; p= 0.83). Symptom ratings were similar between groups at the acute post-injury assessment (median PCSS= 18.5 [7.5-26] vs. 17 [14-40]; p=0.21), but a main effect of group after adjusting for time from injury to assessment indicated the exercise group reported lower symptom severity than the no exercise group across both assessments (p=0.044). The dual-task gait speed of the exercise group was higher than the no exercise group (0.90±0.15 vs. 0.78±0.16 m/s; p=0.02).

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Conclusion: Athletes who were recommended aerobic exercise after concussion did not have worse outcomes than those who were not. Exercise within the first week after concussion does not appear to be associated with detrimental clinical outcomes.

Keywords

mild traumatic brain injury; exercise; treatment; postural balance

Introduction

Concussions and persistent post-concussion symptoms can cause significant disruptions across many domains of function.¹ Current treatment protocols rely substantially on consensus or expert opinion.² As a result, clinicians have highly variable practice patterns related to what testing methods, treatment options, and criteria are used to determine if a patient has sustained a concussion, has fully recovered from the injury, or if a referral to a specialist is needed.³

Among the management strategies available, engaging in physical activity after a concussion has been reported as potentially beneficial in improving patient outcomes.⁴ In 2017, the Fifth International Consensus Statement on Concussion in Sport updated post-concussion physical activity recommendations from waiting until symptoms resolve before beginning activity⁵ to now encouraging light physical activity after a 24-48 hour rest period.² This updated recommendation is based on studies that have observed controlled exercise at a level which does not exacerbate symptoms (i.e. sub-symptom) in the days and weeks after a concussion and determined such exercise is at least safe, if not potentially beneficial.⁶⁻⁸ However, the reliance on symptom provocation to stop exercise in this context may confound its utility given that exercise can cause concussion symptoms in non-concussed individuals.⁹ Thus, further investigation into acute post-concussion exercise is warranted.

Relatively few studies, however, have observed how acute exercise after concussion affects clinical outcomes and recovery time.¹⁰ One recent study reported that conducting exercise tests within ten days of a concussion did not worsen symptom severity or prolong recovery times.¹⁰ This study, along with other prior investigations^{4,6,7} indicate that early exercise after a concussion does not negatively affect recovery time or self-reported symptoms. Objective outcome measures that assess functional abilities beyond self-reported measures may also provide insights into the effects of exercise after concussion.

Along with increased symptom burden, executive dysfunction and postural instability are objective deficits that have been observed following concussion,^{1,11} which may manifest as difficulty in maintaining balance control¹² or in simultaneously executing a motor and cognitive task.¹³ Executive functioning is essential for activities of daily living; dual-task gait evaluations that incorporate a concurrent cognitive task during a walking task have been used to probe these abilities.^{14,15} While sub-maximal aerobic exercise can improve symptom severity for individuals with persistent post-concussion symptoms,^{16,17} more work is needed to identify the association between aerobic exercise, postural stability, and executive functioning soon after a concussion.

The primary purpose of our observational investigation was to examine symptom severity within 48 hours of concussion (initial evaluation) and again 2-7 days post-injury (follow-up evaluation) among collegiate athletes participated in exercise within the first week after concussion compared to those who did not. We also sought to examine the rate of change in symptom severity between time points among collegiate athletes who did and did not participate in early post-concussion exercise. We hypothesized that those who exercised would have lower overall symptom severity at the follow-up evaluation and faster symptom recovery rate relative to those who did not exercise.^{17,18} Our secondary purpose was to examine the association between exercise after concussion with symptom resolution time and postural control outcomes, including dual-task gait and quiet stance errors. We hypothesized that the exercise group would have a shorter symptom duration, and would walk faster during dual-task gait and perform fewer modified Balance Error Scoring System (mBESS) errors compared to the no exercise group at their follow-up evaluations.^{18,19}

Methods

We conducted an observational prospective investigation of athletes enrolled at an NCAA Division I university who were 18 years of age or older and provided written consent to participate in the study. Participants completed a symptom severity questionnaire within 48 hours of injury (initial evaluation), and then completed a symptom severity questionnaire, dual-task, and balance assessment 2-7 days post-injury (follow-up evaluation). The median time between assessments was two days (range=1-7 days). We excluded potential participants if they reported an existing lower extremity injury that may have affected gait abilities, a currently active psychiatric condition, had sustained a concussion within the previous 6 months, if they completed their assessment more than one week after injury, or if they did not complete the symptom or balance control evaluation. Thirteen participants were excluded from the study, resulting in an 85% study response rate. The reasons for exclusion included not completing the symptom evaluation at both time points (n=8), not completing the gait and balance examination (n=4), and undergoing initial testing outside the specified time range after injury (n=1). The Boston Children's Hospital institutional review board approved of this study.

All participants were diagnosed with a concussion by a single board-certified sports medicine physician and were symptomatic at the time of the initial evaluation. Concussion was defined according to the consensus statement by the Concussion in Sport Group as a brain injury either caused by a direct blow to the head, face, or neck, or an impact elsewhere on the body with an impulsive force transmitted to the head, that resulted in the rapid onset of impairment of neurological function.² Decisions pertaining to exercise were made at the discretion of the medical staff and were independent of this observational investigation. No participant was given clearance to return to unrestricted athletic activities within the timeline of this investigation.

We grouped patients based on whether or not they reported participating in exercise in between the time of injury and the follow-up evaluation (exercise after concussion vs. no exercise after concussion groups). The decision to allow exercise was made by the medical provider based on clinical presentation and at the discretion of the team physician consistent

with consensus guidelines,² where after a brief rest period following injury, those who were deemed able to tolerate sub-symptom exercise were prescribed to begin exercise under clinician supervision. The participant confirmation of the type of exercise performed, consistent with prior work.²⁰ Medical decisions were made independent of the study, and we investigated potential confounding variables (age, sex, prior concussion history, pre-injury migraine disorder, preinjury learning disability diagnosis, body size, and time from injury to assessment) pertaining to this grouping assignment to adjust our interpretation of any between group differences.

As this was an observational study, we were unable to perform any group randomization. The type of exercise included either cycling on a stationary exercise bike or light jogging on a treadmill, and compliance with the recommendation was measured via self-report at the follow-up examination. All participants who were given an exercise recommendation reported participation in line with the recommended exercise level (n=13/13; 100% reported exercising at the clinician-specified level). Participants completed exercise bouts at a level which did not provoke symptoms, performed for 10-15 minutes at a self-selected pace under the supervision of a certified athletic trainer, and they did not progress beyond stationary bike or light jogging stages of exercise for this 10-15 minute duration during the study period. If the athlete reported symptom exacerbation, they stopped prior to completion of the protocol in line with consensus guidelines.² If symptom severity returned to, or was better than the previous level the following day, they resumed the same exercise protocol. All participants who completed any supervised exercise were included in the exercise group, and were not excluded on the basis of symptom exacerbation. Intensity, frequency, and duration of exercise sessions were not measured. Athletes were allowed to progress in their physical activity in a stepwise fashion with some low level symptoms as long as exercise did not exacerbate their symptoms.

We assessed symptom severity at the initial and follow-up evaluations using the post-concussion symptom scale (PCSS). Participants rated 22 different concussion symptoms using a scale from 0 (asymptomatic) to 6 (maximum severity). We instructed participants to only rate the symptoms that started at the time of injury and that they had been experiencing in the 24 hours prior to the assessment. This scale was then used to determine symptom duration, calculated as the number of days between the date of injury and the date the athlete reported a 0 on the PCSS.

In addition to the overall PCSS scores, we also calculated symptom severity ratings in different domains (cognitive-fatigue-migraine, affective, somatic, sleep) as previously described.²¹ In order to assess on the rate of PCSS change between the two tests, we calculated the difference in PCSS scores between the follow-up and initial evaluations. Thus, a negative change in PCSS score indicates decreasing symptom severity (clinical improvement), and a positive change in PCSS score indicates worsening symptom severity over time.²²

At the follow-up evaluation, study participants completed a single/dual-task gait assessment.^{23–25} During single-task trials, participants walked at a comfortable pace along the pathway, while during dual-task trials, they walked and simultaneously completed a cognitive test.

The cognitive test, consistent with previous studies,^{24,25} consisted of spelling a 5-letter word backwards, serial subtraction from a 2-digit number by 6s or 7s, or reverse month recitation. Participants wore three inertial measurement sensors attached at the level of the lumbosacral junction and on the dorsum of each foot (Opal Sensor, APDM Inc., Portland, OR). The primary outcome obtained was average walking speed, calculated using Mobility Lab v 2.0.

Participants also completed the mBESS at the follow-up evaluation. During the mBESS, they stood on a solid surface only, as opposed to the original BESS where trials are conducted on a foam pad. The details of the mBESS protocol have been described previously.²⁶ The outcome variable for the mBESS was number of errors committed in each stance. Errors included opening the eyes, lifting hands off hips, taking a step, falling out of the testing position, lifting any portion the foot off the ground, abducting the hip greater than 30 degrees, or staying out of the test position for 5 seconds or more. A lower mBESS score indicates that the participant demonstrated a better ability to remain in the specified posture. Although data were unavailable for gait and mBESS outcomes at the initial evaluation, their inclusion provides a preliminary analysis of how exercise may be associated with objective functional outcomes beyond self-reported outcomes soon after concussion, which have been the most prominent outcomes in the literature to date.^{8,10}

Continuous variables are presented as means (standard deviations) for normally distributed variables and as medians [interquartile ranges] for non-normally distributed variables. Categorical variables are presented as the number present in the group and percentages of the total. We compared demographic variables, medical history, and injury characteristics between groups using independent samples t-tests or Mann-Whitney U tests and Fisher's exact tests. We also compared median difference in PCSS scores between initial and follow up visits and symptom duration between the exercise and no exercise groups using Mann-Whitney U tests. Statistical significance was set at $\alpha < 0.05$ and all tests were two-sided.

In order to determine the effect of exercise after concussion on symptom severity, we used a two-way repeated measures analysis of covariance (ANCOVA) to determine the interactions and main effects for our independent variables: group (exercise vs. no-exercise) and time (initial evaluation vs. follow-up evaluation), while including time from injury to assessment (days) as a covariate. We then performed a series of repeated measures ANCOVAs with the same independent variables and covariate, using each symptom domain severity rating as the outcome measure. If an interaction or main effect reached statistical significance, pairwise follow-up comparisons were conducted and adjusted using the Bonferroni procedure to control Family Wise Type I Error. Gait, cognitive, and balance measures were compared using independent samples t-tests or Mann-Whitney U tests depending on the distribution of the data. Statistical analyses were performed with Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, version 24.0, Armonk, NY, USA: IBM Corp) and Stata (StataCorp, version 15, College Station, TX).

Results

There were a total of 72 student athletes who participated in the study, 13 (18%) who exercised after concussion. The exercise and no exercise groups completed evaluations at

similar initial intervals, but the exercise group completed the follow-up approximately one day later than the no exercise group (Table 1). There was a higher proportion of women in the no exercise group than in the exercise group. A significantly higher proportion of the acute exercise group reported attending class at the follow-up evaluation than the non-exercise group (Table 1). There was no significant difference in initial symptom severity (median PCSS= 18.5 [7.5-26] vs. 17 [14-40]; $p=0.21$), symptom resolution time (median= 13 [7-18] days vs. 13 [7-23] days; $p=0.83$), or time from injury until medical clearance to return to play between the exercise and no exercise groups (median= 15 [11.5-36] vs. 19 [14-26] days; $p=0.46$; mean= 22.5 ± 17.3 vs. 29.4 ± 30.1 days).

The median change in PCSS between initial and follow-up evaluations did not significantly differ between exercise and no exercise groups (median= -4.5 [IQR= $-12.5, 2$] vs. -1 [$-11, 3$] PCSS change; $p=0.62$; Cohen's $d=0.02$). After adjusting for visit time, PCSS scores were significantly lower for the exercise group compared to the no exercise group across the initial and follow-up evaluations (Figure 1; main effect of group: $F= 4.14$; $p= 0.044$). The exercise group reported significantly less severe cognitive-fatigue-migraine symptoms than the no exercise group (Supplementary Table 1; main effect of group: $F= 4.03$; $p=0.047$). Affective symptom ratings significantly decreased for both groups at the follow-up evaluation relative to the initial evaluation (Supplementary Table 1; main effect of time: $F= 3.25$; $p=0.003$; overall mean= 1.1 at visit 1, 0.5 at visit 2). We found no significant main effects of group, time, or interaction effects for sleep or somatic symptom domains (Supplementary Table 1). The acute exercise group walked significantly faster during dual-task conditions than the no exercise group at the follow-up evaluation (Table 2), while single-task gait speed, cognitive accuracy, and mBESS performance were not significantly different between groups. There were no errors committed during double-leg stance, thus, we did not perform any analyses for this condition.

Discussion

The results from our preliminary investigation indicate that light aerobic exercise in the days after a concussion was associated with lower symptom severities. Given the exercise group also reported lower symptom severity initially after injury, our findings may reflect that the group with lower initial symptom severity remained lower across both time points. In either case, our data suggests that exercise does not have a detrimental effect on symptom severity in the first week of a concussion. Furthermore, the similar symptom resolution times between groups suggests that engaging in acute post-concussion exercise does not prolong recovery in a group of collegiate athletes. Although the symptom rate of improvement was marginally better for the exercise group compared to the no exercise group, because of the observational nature of our study, lack of control over group assignment, and potential biases that may have resulted, larger, prospective, randomized intervention studies will be necessary to determine if early exercise after a concussion has a beneficial effect. Furthermore, exercise dosage information (e.g. intensity, frequency, and duration) throughout all post-concussion exercise sessions should be recorded in order to better delineate dose-response effects,²⁷ and the use of outcomes measures beyond symptom severity will provide a more comprehensive insights into the effects of exercise on post-injury outcomes.

The latest guidelines suggest that patients can be encouraged to become gradually and progressively more active while staying below symptom thresholds,² and that strict brain rest (e.g. “cocoon therapy”) is not indicated among concussion patients due to potential detrimental effects.²⁸ While these recommendations represent current best practices, the lower symptom burden for the exercise group in our study does not necessarily indicate a causal effect due to exercise. It is likely that a less severe symptom rating at the time of injury influenced the clinical decision to allow exercise. Our preliminary findings, however, are consistent with prior work. The lack of difference in time to symptom resolution is in line with prior work by Leddy and colleagues (2018) who reported that adolescent athletes who were randomized to an exercise test protocol within the first 9 days of a concussion did not have different recovery outcomes than those randomized to no exercise.¹⁰ Furthermore, Thomas and colleagues (2015) reported better symptom outcomes for patients who underwent two days of rest followed by gradual activity resumption relative to those engaged in strict cognitive and physical rest for five days.⁷ Other research suggests that moderate physical activity within the first seven days of a concussion is associated with significantly fewer symptoms compared to restricted physical activity.⁴ Thus, taken together, it is plausible that early physical activity after a concussion does not negatively affect subsequent recovery. However, other potential confounding variables such as sex, class attendance, and symptom status following concussion may have at least partially contributed to our observed findings. In particular, a lower proportion of the no exercise group reported returning to class by the follow-up exam compared to the exercise group, perhaps due to medical recommendations, symptom status, or other unmeasured factors. Future studies should seek to include each of these factors in planned analyses comparing outcomes among those who do and do not exercise following concussion.

Although participants had better symptom and dual-task gait outcomes at the follow-up evaluation, the lower symptom severity at the initial presentation indicates that their injury may have been less severe. Furthermore, given the lower symptom ratings scores initially, we would expect, based on prior research,⁶ the exercise group to have shorter recovery times. However, there was no significant difference in the rate of symptom reduction between the two assessments between groups which may reflect the relative short follow up period. Interestingly, of the five symptom domains investigated, we identified a significant group effect only in the cognitive-fatigue-migraine domain. As cognitive symptoms may be associated with post-concussion cerebrovascular dysfunction,²⁹ the difference in cognitive symptoms may relate, at least in part, to the exercise performed following concussion.

Preliminary findings from the postural control measures indicated that participants who exercised were able to walk faster during dual-task conditions, but walked similar to those who did not exercise under single-task conditions and completed the mBESS with a similar amount of errors. Cerebrovascular function may be associated with executive functioning and dual-task gait,^{19,30} thus, the acute exercise may have improved the ability to complete the motor element of the dual-task. However, these preliminary findings may also reflect that individuals who have lower symptoms were also able to complete a simultaneous walking and thinking task better than the no exercise group at the time of injury. In prior work, both symptoms and dual-task gait speed were significantly worse for collegiate athletes with a concussion relative to controls,²⁵ suggesting a potential association between these

measurement domains acutely post-injury. Furthermore, 15 minutes of moderate intensity exercise has been reported to improve motor performance during a tandem gait task but not single-leg postural stability.³¹ This aligns with our finding that there was an association between exercise and better dual-task gait performance, but not mBESS performance. The lack of variability by study participants during the mBESS double stance condition also aligns with prior research,³² and suggests the utility of this condition to measure intervention outcomes is limited. Accordingly, implementing an objective and complex element to the multifaceted concussion evaluation may be an effective method to monitor recovery with the implementation of acute post-injury exercise.

There were several limitations within our preliminary study, and our findings should be interpreted in light of them. Primarily, our small sample size, potential clinician bias, and variable timing in post-injury assessments limit the strength of our observations. We were unable to acquire data pertaining to gait and balance outcomes at the initial evaluation and instead only acquired symptom severity data at this time point. In addition, symptom severity was a factor for clinicians providing the recommendation to rest or exercise. Thus, patient outcomes may have been influenced by this initial symptom severity. The exclusion of some participants may have resulted in bias, as some of those excluded may have demonstrated different symptom profiles or responses to exercise. Furthermore, we did not record the duration or intensity of exercise bouts or the sub-exercise physical activity exposure of exercise or no exercise groups, limiting our ability to assign any causal effects pertaining to the different components of the exercise in which participants engaged. Also, there were variable time intervals in between the initial and follow-up evaluations, potentially leading to variability in the amount of symptom recovery observed. In addition, our relatively small and unbalanced sample of participants were from a single academic institution, thus our findings may not be generalizable to other institutions or age groups. We also did not assess pre-injury symptom burden, whether drugs or alcohol were consumed during the test period, or the effect of family history of concussion, each of which may have affected our observed outcomes. Other assessment domains such as cognitive, vestibular, or ocular measures may have also been useful to determine the effects of early exercise after concussion, and future studies should consider their implementation to determine early post-concussion exercise efficacy. Finally, the exercise group had lower symptom scores at the outset. Thus, they may have 1) been more likely to exercise and 2) more likely to have lower symptom scores at follow up. However, the similar decrease in symptom scores for each group between visits, suggests that exercise had no adverse effect on symptoms.

Conclusion

In conclusion, the preliminary findings from our observational study suggest that clearance to participate in exercise within the first week of a concussion is associated with lower symptom severity. While we cannot draw causal conclusions from our design, we did not observe a detrimental effect on symptom severity or symptom duration among athletes who exercised in the first week of a concussion. Future work should account for exercise timing, intensity, duration, and frequency in order to better identify proper exercise prescriptions in the acute post-concussion stage.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Practical Implications

- There was an association between exercising in the first week after concussion and lower symptom severity.
- The causal nature of this association cannot be drawn from our study.
- Our data suggest that exercise did not detrimentally affect recovery when performed within one week of concussion.

Figure 1.

Boxplots describing PCSS scores for the exercise after concussion and no exercise after concussion groups at initial and follow-up evaluations. The range of the box defines the 25th and 75th percentile, and whiskers extending from the box plots define the range of PCSS scores obtained.

Table 1.

Demographic and medical history characteristics of participants who did and did not exercise after concussion (means, SD or n, %)

Variable	Exercise after concussion (n=13)	No exercise after concussion (n=59)	P value
Age (years)	20.1 (1.3)	20.3 (1.3)	0.62
Sex (female)	3 (23%)	30 (51%)	0.12
Prior concussion history	9 (69%)	36 (61%)	0.76
Pre-injury migraine disorder	1 (8%)	5 (8%)	1.0
Diagnosed learning disability	0 (0%)	3 (5%)	1.0
Initial assessment (days post-injury)	0.9 (0.8)	0.6 (0.8)	0.16
Follow-up assessment (days post-injury) *	3.8 (1.8)	2.8 (1.2)	0.02
Height (cm)	176.5 (9.6)	177.8 (10.6)	0.69
Mass (kg)	78.8 (4.9)	81.0 (20.6)	0.74
Attending class at follow-up exam? *	11 (92%)	31 (53%)	0.02
Mode of exercise	Bicycling: 9 (69%) Light jogging: 4 (31%)	N/A	N/A
Sport during injury			
American football	5	18	
Field hockey	1	4	
Ice hockey	0	6	
Basketball	0	4	
Lacrosse	1	2	
Rugby	1	4	
Soccer	0	4	
Volleyball	0	4	
Sailing	0	3	
Softball	1	2	
Crew	0	2	
Wrestling	2	1	
Baseball	1	1	
Swimming	1	0	
Tennis	0	1	
Track and Field	0	1	
Skiing	0	1	
Water Polo	0	1	

* A significantly greater proportion of those who exercised reported attending class at the follow-up exam compared to those who did not exercise. The exercise group's follow-up examination was significantly later post-injury than the no exercise group.

Table 2.

Comparison of gait and balance outcomes obtained at the follow-up evaluation for exercise after concussion and no exercise after concussion groups.

Variable	Exercise group	No exercise group	P value	Cohen's d
<i>Gait evaluation</i>				
Single-task gait speed (m/s)	1.03 [0.913-1.14]	0.987 [0.912-1.10]	0.39	0.31
[†] Dual-task gait speed (m/s) *	0.903 (0.150)	0.782 (0.158)	0.02	0.77
<i>Cognitive evaluation</i>				
Single-task accuracy (% correct)	98.0 [97.0-100]%	98 [96.0-100]%	0.78	0.20
Dual-task accuracy (% correct)	100 [94.0-100]%	99 [95.0-100]%	0.77	0.21
<i>Modified BESS evaluation</i>				
Single leg stance errors	1.50 [0.50-6.00]	3.00 [1.00-5.00]	0.47	0.17
Tandem stance errors	1.00 [0.00-3.00]	1.00 [0.00-2.00]	0.84	0.17

[†] Normally distributed variable, reported as mean (SD). All other variables were not normally distributed and are reported as median [IQR].

* p < 0.05.