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Programmed Physical Exertion in Recovery From Sports-Related Concussion: A Randomized Pilot Study

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Abstract
Although no data exist, general practice recommends only rest following concussion. This randomized clinical trial found that programmed physical exertion during recovery produced no significant differences in recovery time between groups of participants. However, high levels of exertion were deleterious. This study provides initial evidence that moderate physical activity is a safe replacement behavior during recovery.

Recommending "rest" has become the treatment of choice in the management and recovery of mild traumatic brain injury (mTBI) and sports-related concussion (SRC) (Leddy, Sandhu, Sodhi, Baker, & Willer, 2012). The sports medicine literature is generally in agreement that cognitive and physical rest is appropriate until symptoms resolve, as strenuous cognitive and physical activity may exacerbate symptoms and delay recovery (McCrory et al., 2013). In contrast, research from both post-concussion and rehabilitation literature suggests that moderate exercise is effective for treating brain injuries (see Grealy, Johnston, & Rushton, 1996; McCrea et al., 2009).

While retrospective studies indicate that cognitive and physical rest may decrease symptoms and improve cognitive performance post-concussion (Moser, Glatts, & Schatz, 2012), other research suggests little or no beneficial effect of physical rest (Willer & Leddy, 2006; Gibson, Nigrovic, O'Brien, & Meehan, 2013).

There is some evidence in the adult literature that noncontact aerobic exercise may play a role in rehabilitation of individuals experiencing prolonged recovery or Post-Concussion

Syndrome (PCS: Leddy et al., 2013). However, no randomized clinical trials have studied the effect of exercise in youth recovering from sports-related concussion. The present study is a pilot randomized clinical trial (RCT) that sought to document the effect of controlled, programmed daily physical exertion (stationary bike riding protocol) on recovery after SRC. The central aim of the study was to determine the effect of moderate levels of prescribed physical exertion on recovery from concussion. Our hypothesis was that exertion would have no effect (null) and thus refute the hypothesis that exertion would negatively impact recovery. An alternate hypothesis was that exercise would have a positive effect on recovery.

Method

Participants

Twenty-eight recently concussed college athletes were recruited and consented for this study during the 2010–2013 academic years. Athletes were randomly assigned to either standard concussion recovery recommendations ("Standard": 12 females, 3 males), or prescribed daily physical exertion at a moderate level ("Exertion": 8 females, 5 males). For athletes to qualify for this study, their injury severity was judged as not preventing them from participating in the exercise protocol. The institutional review board approved this study. All participants were paid $25.00.

Procedures

The initial clinical evaluation was completed as soon as athletic trainers (ATC) were able to assess the athlete. At the first assessment, athletes were asked to participate in this study. If agreed, a research-trained ATC met with the athlete, consented, and enrolled them in the study. From that point on, athletes met with the research ATC on a daily basis to monitor status and activity. Five measures were used to assess athletes throughout the study. These included the use of health and demographics questionnaires, the ImPACT (Immediate Post-concussion Assessment and Cognitive Test) neurocognitive test battery, the Borg CR10 RPE scale (Rated Perceived Exertion), the Post-ride symptom change rating: an experimental Likert scale to rate the changes in symptoms after the bike exertion, and Actical actigraphs to measure the amount of physical activity, day and night.

An actigraph was placed on each athlete for monitoring ambient activity levels. When test scores, balance, and symptoms had returned to baseline, the athlete was determined to be recovered for the purposes of this study (primary outcome). At any point, if symptoms emerged, the exercise protocol was stopped for 24 hours and then reinstituted.

Athletes assigned to the exertion protocol rode a Schwinn Airdyne stationary bicycle at a perceived exertion level of "mild" to "moderate" (0 to 6 on the RPE scale: Borg, 1998). This version uses a 10-point scale with a visual analog, with 0 for no exertion, to 6 for moderate-hard, to 10 for very, very hard. At the end of the session, each athlete rated the level of perceived exertion they achieved during the ride. They also rated changes in symptoms from pre-ride symptom levels ("post-ride symptom change rating"). Sessions were discontinued if symptom increases became uncomfortable to the athlete. No athlete reported continued increase in symptoms. At any point, the consulting MD could discontinue an

athlete if concerns arose. One athlete was discontinued due to general lack of recovery (not increase in symptoms). Athletes rode 20 minutes unless they felt uncomfortable. They were monitored daily until they reached the clinical recovery point, which included being symptom-free after physical exertion. Post-ride symptom check was done immediately after each riding session.

In the standard condition, athletes were instructed to engage in no systematic exertion beyond the normal activities required for school (walking to classes, studying, etc.). Other than examining Actical data, there was no system for verifying level of activity in the standard condition.

Analysis

Primary analysis was a 2-group analysis of variance with time to recovery as the dependent variable. Regression-based *z*-scores (RBz) were calculated for the ImPACT cognitive and symptom scores; the RBz represents the amount of score change from baseline to post-injury, controlling for the level of the baseline (and thus regression to the mean), and practice effects (Hinton-Bayre, 2012; Temkin, Heaton, Grant, & Dikmen, 1999). ImPACT composites for Verbal Memory, Visual Memory, Visual-Motor Speed, Reaction Time, and Total Symptom score were analyzed. The median number of days from injury to first assessment was two days. Regression parameters were taken from a previous study of non-contact athletes at this institution who had test–retest data (McAllister et al., 2012).

To explore the relationship of activity variables (actigraph) to days of recovery for the entire group, subjects who took more than 50 days to recover were removed ($N = 3$), as these participants were statistical outliers and not entirely compliant with the study's protocol. The average minutes per day of vigorous energy expenditure (as defined by the Actical program) was calculated for each athlete, as was the average amount of mental exertion. The distribution of scores for both was normal (Kolomogorov-Smirnov one-sample test).

Results

One hundred fifty-seven concussed athletes were approached. Thirty-three athletes agreed to participate, with five dropping out ("too busy") to give a 18% recruitment rate. No significant sex by group difference were found ($\chi^2(1) = 1.163$, $p = .281$), although the high proportion of females in this study may mask differences in larger samples. There was no difference between the distributions or medians for the number of days to injury to the start of study participation. There were also no differences between groups on any of the other independent variables: severity of injury (ImPACT composite and ImPACT symptom total change scores: *p*-values all >.10: Table 1), or number of previous concussions (independent samples median test, $p = .114$).

Between Group Analyses

The between-group time to recovery was analyzed both by the number of days to recovery, and the proportion of athletes who had prolonged recovery (greater than 2 weeks). The median number of days to recover was no different by group (exertion group: $N = 28$; median of 15 days, range 5–61; standard group median of 13 days, range 6–56: Independent

Table 1. Recovery Periods and Means (Standard Deviations) of Change in Neuropsychological Variables and Symptoms

Group	N	<2 Weeks Recovery	>2 Weeks Recovery	Verbal Memory	Visual Memory	Visual Motor Speed	Reaction Time	Symptom Total
Standard	15	9	6	–0.39 (.74)	–0.68 (1.29)	0.36 (1.57)	–1.15 (1.25)	2.07 (2.35)
Exertion	13	6	7	–0.87 (.75)	–1.48 (1.45)	0.20 (1.45)	–1.30 (1.46)	2.29 (2.04)

Samples Median Test, Fischer's exact $p = .705$). Slightly more members of the exertion group had prolonged recovery (greater than two weeks: 53%), this was non-significant: $\chi^2(1) = .537$, $p = .464$ (Table 1).

Fidelity to the exertion protocol was high: perceived exertion for 93% of the bike sessions (rides) was at the prescribed level (light to moderate exertion: 132 of 142 rides). Ten percent of the bike rides were not completed due to feeling badly (128 of 142 rides completed).

Bike Exertion Analysis

After each session, riders recorded the degree to which 141 symptoms changed from pre-ride levels. At the end of the ride, each rider was queried about each symptom and whether or not the level was "the same or better," "slightly worse," "moderately worse," or "significantly worse" than before riding. Overall, significantly more bike-rides resulted in some level of symptom change (41%) versus no change (59%): $\chi^2(1) = 4.76$, $p = .03$. There was a 1.8 symptom increase per ride rated in "light" rides (i.e., number of light symptom increases divided by the total number of light exertion rides), a .55 symptom increase in "moderate" rides, and seven symptoms increased per "strenuous" ride.

To determine if symptom provocation early in recovery was detrimental to outcome, we entered the number of symptom increases on the first day of riding into a regression equation with the length of time to recovery. First-day symptom increase was not related to recovery time: $R^2 = .12$, $p = .252$.

For the reduced total sample ($n = 24$, one subject had missing actigraph data), the average amount of daily vigorous physical exertion accounted for a small but significant amount of variance in recovery time with more activity increasing recovery time: mean = 7.02; s.d. = 2.18; $R^2 = .18$, $p = .039$.

Discussion

In this pilot randomized clinical trial to determine the effect of physical exertion on recovery from concussion, moderate physical activity did not have a significant effect on time to recovery. During exertional challenge, the most frequently endorsed symptoms after

1. The 14 symptoms were only symptoms relevant to the situation (from the Post Concussion Symptom Checklist: headache, dizziness, fatigue, blurred vision, poor concentration, longer to think, light sensitivity, nausea, double vision, noise sensitivity, restlessness, irritable, depression/sadness, frustrated/impatient).

riding were headache, dizziness, and fatigue. Importantly, symptoms after moderate exertion only occurred initially, but soon dissipated over the following rides. On the other hand, the amount of measured vigorous activity was related to recovery, with more exertion retarding recovery.

While studies of exercise as a treatment in concussion have been encouraging, the optimal amounts and timing of exercise/exertion relative to sports concussion has yet to be determined. This study provides initial evidence that starting exercise relatively early after injury, and that mild symptom increases should not interfere in recovery. However, vigorous activity was deleterious.

There are several features of this study that limit the generalizability of the findings. First, the sample size was small for the between group analysis. Second, the high percentage of females in the study was unusual for concussion studies and may have biased the findings.

Previously, common sense has dictated the need to limit mental and physical exertion after concussion (Gioia et al., 2010). However, in this pilot study, moderate physical exertion appeared to be a benign factor in the recovery process. Further studies are needed to provide more specific guidance regarding frequency, timing and other aspects of moderate physical exertion as a treatment in concussion management.

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