Return to Activity after Concussion Affects Dual-Task Gait Balance Control Recovery

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ABSTRACT

HOWELL, D. R., L. R. OSTERNIG, and L.-S. CHOU. Return to Activity after Concussion Affects Dual-Task Gait Balance Control Recovery. Med. Sci. Sports Exerc., Vol. 47, No. 4, pp. 673–680, 2015. Background: Recent work has identified deficits in dual-task gait balance control for up to 2 months after adolescent concussion; however, how resumption of preinjury physical activities affects recovery is unknown. Purpose: The objective of this study is to examine how return to activity (RTA) affects recovery from concussion on measures of symptom severity, cognition, and balance control during single-task and dual-task walking. Methods: Nineteen adolescents with concussion who returned to preinjury activity within 2 months after injury and 19 uninjured, matched controls completed symptom inventories, computerized cognitive testing, and single-task and dual-task gait analyses. Concussion participants were assessed at five time points: within 72 h, 1 wk, 2 wk, 1 month, and 2 months postinjury. Control participants were assessed at the same time points as their matched concussion counterparts. RTA day was documented as the postinjury day in which physical activity participation was allowed. The effect of returning to physical activity was assessed by examining the percent change on each dependent variable across time before and directly after the RTA. Data were analyzed by two-way mixed effects ANOVAs. Results: After the RTA day, concussion participants significantly increased their total center-of-mass medial/lateral displacement ($P = 0.009, \eta^2 = .175$) and peak velocity ($P = 0.048, \eta^2 = 0.104$) during dual-task walking when compared with pre-RTA data, whereas no changes for the concussion group or between groups were detected on measures of single-task walking, forward movement, or cognition. Conclusions: Adolescents with concussion displayed increased center-of-mass medial/lateral displacement and velocity during dual-task walking after RTA, suggesting a regression of recovery in gait balance control. This study reinforces the need for a multifaceted approach to concussion management and continued monitoring beyond the point of clinical recovery. Key Words: SPORT CONCUSSION, GAIT STABILITY, RECOVERY, PHYSICAL ACTIVITY

Much attention has been given in recent years to the issue of diagnosis, treatment, and management of concussion. Grading scales have been used to quantify injury severity and guide protocols related to return to physical activity; however, these have been discarded gradually as such scales may not fully encompass the physiological disturbances and consequent resolution induced by a concussive event (21). Current best-practice treatment protocols include a period of complete physical and cognitive rest immediately after injury followed by a stepwise reintegration into preinjury activities once symptoms have been resolved and cognitive and balance functions return to preinjury levels (14,22).

Although previous investigations have revealed a vast amount of information regarding the pathophysiology of concussion (5,10), the decision of when an individual returns to physical or cognitive activities after concussion remains among the most difficult and controversial issues in clinical sports medicine (7). Despite recent efforts by state (31) and various professional associations (7), no consistent regulations currently exist for timing of return to preinjury activities.

Various concussion position statements have discussed elements used in the decision of when to begin the resumption of physical activities (14,21,22), whereas other studies have addressed the relation between concussive impacts and healing rates (2), and the time course of physiologic recovery after concussion (25). However, no investigations have systematically examined how resuming preinjury levels of activity affects cognitive and motor function. Barr et al. (1) have reported that physiological recovery may extend beyond clinically observed recovery, suggesting that traditional testing techniques may not be sufficiently sensitive to detect subtle deficits after concussion. As it has been documented that football players who sustain a concussion are up to three times more likely to sustain a second concussion within the same season compared
with those who have not sustained a concussion (11), premature return to play may be a potential factor in such increased vulnerability.

A period of metabolic vulnerability in brain tissue has been reported to occur after a concussive event (10), as well as alterations to cerebral blood flow (19), neurochemical impairments (32), and electrophysiological deficits (25), all of which may contribute to symptom generation and other neurologic dysfunction. A functional magnetic resonance imaging investigation also revealed that despite similar working memory performance for concussion patients compared with a cohort of matched controls, brain activation differences were still present at 2 months after concussion (6). Other recent work has identified cognitive deficits in concussion patients compared with healthy individuals for up to 2 months postconcussion on measurements of attention and task switching (15). Because of these various impairments to the brain after injury, a secondary insult of modest intensity may cause further impairment to neuronal function (10,35) and thus prolong the recovery process (32). These pathological changes to the brain after injury underlie the current recommendation to refrain from exercise after concussion until cleared by a physician to do so (22).

One method to assess recovery after concussion is to measure gait balance control during dual-task walking (16,23). Gait stability during dual-task walking may be particularly sensitive to long-term disruptions after concussion and has been suggested to be a well-suited variable for sensitive detection of pathological behavior related to concussion (8,18). This type of test uses attention-demanding, high-level ability (34) and, when used to identify the duration of motor impairments after concussion, revealed that deficits to gait balance control were present across 2 months of testing postinjury (16). However, the role return to activity (RTA) played in these results is unknown. Using a dual-task protocol, Parker et al. (23) demonstrated a significant regression in gait stability from a 2-wk assessment to a 1-month assessment after concussion in a group of young adults who returned to activity within 2 wk of the injury. It was suggested that motor ability may not have been sufficiently recovered before returning to activity and may have been influenced by enhanced susceptibility to the effect of brain injury resulting from the return to physical activity.

Despite the lack of a current gold standard for the clearance of individuals to return to physical activity after concussion, healthcare professionals are nonetheless asked to provide such clearance. This remains a challenging task despite many recent protocol developments (7). Further complicating this clinical decision is the vulnerability of the injured person to a second concussion (17) and the possibility that premature return to physical activity may increase the risk of reinjury or prolong recovery. Therefore, the purpose of this study was to prospectively and longitudinally examine a cohort of adolescents who returned to activity within 2 months of injury and to observe how the return to physical activity affects recovery from concussion. This was done by examining adolescents with concussion before and after returning to preinjury activities on measures of cognition, symptom severity, and balance control during single-task and dual-task walking. It was hypothesized that after concussion, returning to physical activities within 2 months postinjury would disrupt dual-task walking recovery to a greater degree than symptom recovery, cognitive recovery, or single-task walking recovery.

METHODS

Participant identification. Individuals who sustained a concussion were diagnosed and identified for potential inclusion in the study by a healthcare professional (certified athletic trainer or physician). Concussion diagnosis was defined according to McCrory et al. (21) as an injury caused by a direct blow to the head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head, resulting in impaired neurologic function and acute clinical symptoms. Each participant who was enrolled in the study after a concussion was matched with a healthy control participant by sex, height, mass, age, and sport.

Before data collection, the institutional review board reviewed and approved the study protocol. All participants and parents/guardians (if under the age of 18 yr) provided written consent to participate in the study. Permission was also granted by the respective school districts to conduct testing with student participants.

Each participant who sustained a concussion was removed from the injury site on the day of the injury and did not return to any physical activities or preinjury levels of participation until cleared by a physician in accordance with state law. Concussion management decisions regarding the RTA day were made independent from the study by the attending physicians. Exclusion criteria for all prospective participants in the study included the following: 1) lower extremity deficiency or injury, which may affect normal gait patterns; 2) history of cognitive deficiencies, such as permanent memory loss or concentration abnormalities; 3) history of three or more previous concussions; 4) loss of consciousness from the concussion lasting more than 1 min; 5) history of attention-deficit hyperactivity disorder; or 6) a previously documented concussion within the past year. Consistent with previous work (15), individuals with three or more previous concussions were ineligible to participate in the study to ensure, to the extent possible, the exclusion of participants experiencing chronic mild traumatic brain injury, and those who experienced loss of consciousness for more than 1 min were excluded because of the role this sign plays in concussion management modification (21). A verbal medical history was taken by a certified athletic trainer for all participants upon their first visit to the laboratory to confirm that all criteria were met for inclusion in the study.

Testing time points. A prospective, repeated-measures design (15,16) was used in which each participant reported to the laboratory and was tested at five time points: within 72 h of sustaining a concussion as well as approximately 1 wk, 2 wk, 1 month, and 2 months postinjury. Control participants

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were initially assessed and then tested similarly according to
the same testing schedule as concussion participants.

The RTA day for each concussion participant was docu-
mented because the specific day participation in physical ac-
tivities was allowed by the attending physician or healthcare
provider. Consistent with the study by Prichep et al. (25),
decisions for the RTA day were made by attending healthcare
professionals using conventional methods and were made
independent of study-related data. The concussion partici-
pants who returned to physical activity within the 2 months
of testing were analyzed in the current study along with their
individually matched control participants.

In this study, it was necessary to control for variability of
the RTA day within the group of concussion participants. To
achieve this, the effect of returning to physical activity was
assessed by evaluating the percent change (\(\% \Delta\)) in the de-
pendent variables (identified below) for each concussion
participant between specific testing time points both before
(pre-RTA) and after (post-RTA) the RTA day. The \(\% \Delta\) in
each variable occurring between the two testing days im-
mediately before the RTA day (prereturn 1 and prereturn 2)
and between the testing day immediately before and after the
RTA day (prereturn 2 and postreturn 1) was measured.

The pre-RTA percent change (from prereturn 2 to
prereturn 1) and post-RTA percent change (from prereturn 1
to postreturn 1) were calculated according to the following:

\[
\% \Delta \text{Pre-RTA} = \frac{(\text{prereturn } 1 - \text{prereturn } 2)}{\text{prereturn } 1};
\]

\[
\% \Delta \text{Post-RTA} = \frac{(\text{postreturn } 1 - \text{prereturn } 1)}{\text{prereturn } 1}.
\]

Data from each control participant were evaluated at the
same time points as their matched concussion counterpart.

**Dependent variables.** All participants in the study were
assessed on measures of balance control of single-task and
dual-task walking, cognition, and clinical symptoms, detailed
in previous investigations (15,16). During gait analysis, par-
ticipants walked barefoot at a self-selected speed along a 15-m
long level walkway under two conditions: walking with undivided attention (single-task) and walking while concur-
rently completing a continuous auditory Stroop test (dual task).
The continuous Stroop test consisted of the participants listen-
ing to four auditory stimuli while walking: the recorded words
“high” or “low,” each spoken in a high or low pitch. Particip-
ants were instructed to correctly identify the pitch of the word,
regardless of whether the pitch was congruent with the meaning
of the word. Each of the four stimuli was presented in random
order at a specific time while walking. The first stimulus was
presented once participants had achieved a steady-state gait and
was triggered by a photocell located several steps after gait
initiation. Each of the three subsequent stimuli was presented
one second after the previous response while the individual
continued to walk. Participants were not instructed to focus
attention specifically on either the walking task or the cognitive
task but to continue walking while correctly responding to each
stimulus. Eight to 10 consecutive trials were completed for each
of the conditions (single task and dual task), and the mean value
for each participant was then used in further analysis.

A set of 29 retroreflective markers were placed on bony
landmarks of the participant (12), and whole body motion
analysis was performed using a 10-camera motion analysis
system (Motion Analysis Corp., Santa Rosa, CA) at a
sampling rate of 60 Hz to capture and reconstruct the three-
dimensional trajectory of each marker. Marker trajectory
data were low-pass filtered using a fourth-order Butterworth
filter with a cutoff frequency set at 8 Hz. Whole body cen-
ter of mass (COM) position data were then calculated as the
weighted sum of all body segments, with 13 segments represen-
ting the whole body. For each trial, data were ana-
yzed for one gait cycle, defined as heel strike to heel strike
of the same limb. During the gait cycle, the range of medial/lateral
COM displacement was obtained. The anterior and medial/lateral linear COM velocities were calculated using
the cross-validated spline algorithm from COM positions
(33), and the peak velocities in both directions were identi-
fied. Individuals experiencing a concussion have previously
been reported to exhibit a greater and faster COM motion in
the frontal plane with a reduced sagittal plane motion com-
pared with matched controls (16,23). A reduction (negative
\(\% \Delta\) value) in medial/lateral COM displacement and velocity
variables indicates improvement of gait balance control pre-
or post-RTA, whereas an increase (positive \(\% \Delta\) value) indicates
a worsening of gait balance control pre- or post-RTA. In
contrast, a positive \(\% \Delta\) peak anterior COM velocity value
indicates improvement pre- or post-RTA, whereas a negative
\(\% \Delta\) peak anterior COM velocity value indicates worsening
pre- or post-RTA.

Assessment of cognitive function was performed using two
computerized tests: the Attentional Network Test (ANT
(9,15)) and the Task Switching Test (TST (15,20)). The ANT
probes the efficiency of three distinct attentional components
(alerting, spatial orienting, and conflict resolution) and has
been investigated in adolescents with concussion previously
(15). For this test, the individual fixates on a cross in the
center of a computer screen and responds as quickly and ac-
curately as possible by pressing one of two arrow keys, in-
dicating the direction of a central arrow presented directly
above or below the cross (target arrow). The target arrow is
accompanied by two flanker arrows positioned on either side
of the target arrow, which may point in the same or opposite
direction of the target arrow. The primary dependent variable
investigated was the conflict effect, which is measured as the
accurate response median reaction time difference between
two conditions: trials in which the target arrow is accompa-
nied by two congruent flanker arrows (arrows pointing in the
same direction) versus trials in which the arrow stimulus is
accompanied by two incongruent flanker arrows (arrows
pointing in the opposite direction). The conflict effect probes
conflict resolution, and a greater reaction time difference score
between groups/testing days indicates poorer performance in
the ability to resolve conflict. A reduction (negative \(\% \Delta\) value)
on the conflict effect variable indicates improvement of conflict resolution ability pre- or post-RTA, whereas an increase (positive \(\% \Delta\) value) indicates a worsening pre- or post-RTA.

The TST specifically tests the ability to flexibly switch between competing task or stimulus–response rules (27) and has also been investigated in a cohort of adolescents with concussion previously (15). Participants are required to switch between responding congruently and incongruently to the position of a visual stimulus on a computer screen on every second trial in a sequence. Within each trial, the participant responds to the position of a circle presented in a horizontally configured rectangular box by pressing the right or left arrow key on a standard computer keyboard as quickly and accurately as possible, according to the specific rules of the test. For the congruent trial rule, participants press the arrow key corresponding to the left or right position of the circle inside the rectangle for two consecutive trials. The incongruent trial rule begins on the next trial, which requires the participant to switch to pressing the arrow key that is opposite to the position of the inside of the rectangle for two consecutive trials. Hence, the participant switches rules every two trials (congruent–congruent/incongruent–incongruent). The primary dependent variable, the switch cost, measures the response time difference between trials on which the task changes (switch trials) and trials on which the task stays the same (no-switch trials). A higher switch cost indicates greater difficulty in adhering to the congruent/incongruent rules. A reduction (negative \(\% \Delta\) value) on the switch cost indicates improvement of task switching ability pre- or post-RTA, whereas an increase (positive \(\% \Delta\) value) indicates a worsening pre- or post-RTA.

Clinical symptoms were assessed at each visit to the laboratory using a 22-symptom inventory adapted from the Standardized Concussion Assessment Tool version 2 (SCAT2 (21)), with each symptom ranked on a Likert scale from 0 to 6, resulting in a range of scores from zero (no symptoms) to 132 (maximum severity on all symptoms). Absolute change values were calculated for symptom scores for pre- and post-RTA. A negative change value indicates fewer symptoms reported pre- or post-RTA and therefore an improvement in the symptom score, whereas a positive change value indicates an increase in symptoms reported pre- or post-RTA and therefore a worsening in the clinical symptom score.

Data were analyzed by two-way mixed effects analyses of variance for each dependent variable to determine the effect of group (concussion and control) and time (pre-RTA and post-RTA) and the interaction between the two. For all omnibus tests, significance was set at \(P < 0.05\). Follow-up pairwise comparisons were examined using the Bonferroni procedure to control family-wise Type I error and reported with \(P\) values corrected in this way. Effect size estimations for mean differences are reported as partial eta squared \((\eta_p^2)\) values. All statistical analyses were performed with SPSS version 20 (SPSS, Chicago, IL).

RESULTS

Study participants. Twenty-five local high school students who experienced a concussion while participating in school sports and 25 individually matched control individuals completed the study protocol. Of the 25 individuals who sustained a concussion, 19 individuals (16 men/3 women) returned to physical activity within the 2 months of testing after the injury yielding 19 pairs of concussion and control

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<th>Concussion Group</th>
<th>Control Group</th>
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<tr>
<td>Sex (n)</td>
<td>16 men/3 women</td>
<td>16 men/3 women</td>
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<tr>
<td>Age (yr)</td>
<td>15.4 ± 1.4</td>
<td>15.6 ± 1.1</td>
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<tr>
<td>Height (cm)</td>
<td>171.7 ± 5.8</td>
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<td>68.6 ± 13.3</td>
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<td></td>
<td>Soccer: 4</td>
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<tr>
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<td></td>
<td>Volleyball: 1</td>
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FIGURE 1—Total COM medial/lateral displacement pre- and post-RTA \(\% \Delta\) (mean ± SE). For concussion participants, results indicated an improvement during dual-task walking pre-RTA while demonstrating a worsening of COM frontal plane motion control post-RTA (A). No significant results were detected during single-task walking (B). *Significant difference between periods for the concussion group. †Significant difference between concussion and control groups.
data used for study analyses. Six of the 25 individuals with concussion did not return to physical activity within 2 months postinjury, and their data were not used in the study.

No significant demographic differences were observed between the concussion and control groups for age, height, or mass (P > 0.65, Table 1). Concussion participants were assessed at 2 ± 0.7, 8 ± 1.8, 17 ± 3.8, 30 ± 2.8, and 58 ± 2.3 d after injury. Control participants underwent an initial assessment and also at 7 ± 1.8, 16 ± 4.7, 30 ± 3.5, and 57 ± 6.4 d after the initial assessment. No study participant reported sustaining a concussion during the testing period. The mean RTA day for all concussion participants who returned to physical activity within the 2 months of testing was 23.5 ± 14.4 d postinjury, ranging from 7 to 57 d postinjury.

**Dual-task walking.** A significant group–time interaction was observed for the changes in dual-task COM medial/lateral displacement (F(1, 36) = 7.65, P = 0.009, ηp² = 0.175; Fig. 1A). A mean pre-RTA decline of 11.7% in medial/lateral displacement was found for the concussion group, suggesting improved COM control from prereturn 2 to prereturn 1 time points. However, a mean post-RTA increase of 11.8% for this variable was observed in the concussion group, which was significantly greater than the pre-RTA change, suggesting significant worsening of COM control over the post-RTA period (follow-up comparison: P = 0.005, mean difference = 23.6%; Fig. 1A). The concussion group mean post-RTA %Δ in medial/lateral displacement was also significantly greater than that of the controls for the same time point measurements (follow-up comparison: P = 0.002, mean difference = 20.5%; Fig. 1A).

Analysis of the peak COM medial/lateral velocity during dual-task walking also revealed a significant group–time interaction (F(1, 36) = 4.20, P = 0.048, ηp² = 0.104; Fig. 2A). The mean pre-RTA %Δ for concussion participants was −16.5%, suggesting improved control of peak COM medial/lateral velocity from prereturn 2 to prereturn 1 time points. Similar to the medial/lateral displacement findings, a mean post-RTA increase of 23.9% in medial/lateral velocity was
observed in the concussion group, which was significantly greater than the pre-RTA value, suggesting worsening of COM velocity control over the post-RTA period (follow-up comparison: \( P = 0.010 \), mean difference = 40.2%); Fig. 2A). No significant findings were observed for the control group.

The results for peak COM anterior velocity during dual-task walking showed a main effect of time (\( F(1, 36) = 11.13, P = 0.002, \eta^2_p = 0.236 \); Fig. 3A) and indicated a significant decrease in the %Δ of peak COM anterior velocity between pre-RTA and post-RTA periods. No significant between-group differences were detected for this variable.

**Single-task walking.** The total COM medial/lateral displacement, peak COM medial/lateral velocity, and peak COM anterior velocity data during single-task walking revealed no significant interactions or main effects (Figs. 1B, 2B, and 3B). No significant interactions or main effects of time or group were observed in single-task or dual-task conditions for step width.

**Cognitive tests.** Analysis of the conflict effect variable of the ANT revealed a main effect of time (main effect of time; \( F(1, 36) = 5.25, P = 0.028, \eta^2_p = 0.127 \); Fig. 4A). The mean pre-RTA %Δ for both groups of participants was -25.1%, indicating an improvement in conflict effect scores from prereturn 2 to prereturn 1 time points. The mean post-RTA %Δ for both groups was 2.5%, indicating little change between prereturn 1 and postreturn 1 time points. However, no between-group differences were found for the conflict effect. Switch cost analysis revealed no main effects of group, time, or interactions between the two (Fig. 4B).

**Clinical symptoms.** The evaluation of pre- and post-RTA changes in symptom scores revealed a significant group-time interaction (\( F(1, 36) = 7.55, P = 0.009, \eta^2_p = 0.173 \); Fig. 5). The mean pre-RTA change was -16.8 for concussion participants, indicating an improvement of clinical symptoms from the prereturn 2 to prereturn 1 time points. This value was significantly greater than that of the controls (follow-up comparison: \( P < 0.001 \), mean difference = 17.1) who showed very little change for either testing interval (Fig. 5).

Follow-up comparisons for the concussion group indicated that the mean pre-RTA and the mean post-RTA changes were significantly different (follow-up comparison: \( P < 0.001 \), mean difference = 17.7); however, the mean post-RTA change was 0.8, suggesting clinical symptom stability after RTA (Fig. 5).

**DISCUSSION**

The findings from this study indicate that pre-RTA, the adolescents with concussion reduced their medial/lateral displacement and velocity during dual-task walking, suggesting an improvement in gait balance control, while significantly increasing these frontal plane motion variables during dual-task walking post-RTA, suggesting a worsening of frontal plane COM control after RTA. However, similar comparisons...
for clinical symptoms, single-task walking, COM forward velocity, and cognition indicated improvement or stability in both groups across the same testing periods. These data suggest that frontal plane motion during dual-task walking may be more sensitive to the effects of RTA after concussion than sagittal plane measurements, single-task walking, cognitive functions, or clinical symptoms and may reveal a possible regression in gait stability after RTA.

A recent investigation by Teel et al. (30) found that participants who sustained a concussion in the past week performed at the same level as control participants on traditional cognitive assessments although still exhibiting pathological dysfunction of brain electrical activity. It was suggested that current tools used to assess RTA after concussion may not possess the required sensitivity to detect such deficits after injury. It has been suggested by others that static balance ability (24) and dynamic balance control (23) may not be fully recovered before the decision to return athletes to activity. Dual-task assessments have been explored as a means to evaluate the readiness for functional return to sport activity (26) or military duty decisions (29), and the incorporation of a cognitive task while simultaneously performing a motor task has been reported to increase the sensitivity of concussion resolution detection compared with a single-task motor assessment (28). These studies are in agreement with the data presented in the current study that suggest that dynamic balance control may require a longer period to recover than standard clinical tests used to determine the timing of RTA.

Previous work has identified impairments to gait balance control through analyses of frontal and sagittal plane COM motion in elderly individuals as well as in individuals with concussion (12,16,23). However, in the current study, the cohort of adolescents with concussion demonstrated a regression of recovery in frontal plane COM motion control post-RTA (Figs. 1A and 2A), whereas very little change occurred in sagittal plane movement post-RTA (Fig. 3A). This suggests that frontal plane motion variables may be more sensitive detectors of gait imbalance after concussion than sagittal plane parameters. Frontal plane motion appears to be particularly well suited to provide information about the ability to control whole body motion and potentially identify those who are at risk for imbalance (13,16). A regression in recovery of side-to-side motion control associated with RTA after concussion could potentially affect vulnerability to further injury.

In the present investigation, the ANT and TST cognitive assessments revealed that both the concussion and control participant scores improved during the pre-RTA period and remained stable post-RTA (Fig. 4). This suggests that a possible learning effect occurred pre-RTA in both groups, which diminished post-RTA because no appreciable change was noted from prereturn 1 to postreturn 1 time points for either group. The explanation for this finding is indefinite. It is possible that the participants had reached a learning curve asymptote by prereturn 1, which was not affected by RTA, or that the improvement noted in pre-RTA was interrupted by RTA. Previous work reported learning effects for the ANT and TST for adolescents with concussion and matched control participants over 2 wk postinjury (15). Although a significant between-group raw score difference remained over 2 months postinjury, the effect of RTA was not analyzed in that study. In the current study, no changes were seen in the rate of improvement between groups.

Results indicated a significant improvement for concussion group self-reported symptom severity scores pre-RTA but very little symptom severity change post-RTA (Fig. 5). Because the mean post-RTA change for concussion participants was near zero (mean = 0.8), it appears that RTA did little to elicit either positive or negative changes in symptom severity. Thus, the self-reported symptom severity for individuals with concussion may not be affected by the RTA, in contrast to frontal plane movement during dual-task walking, which was negatively affected by RTA (Figs. 1A and 2A). Consistent with other literature, this result suggests that objective assessment techniques may reveal longer lasting postconcussive features than subjective symptom reporting (3,15). Further, a previous study has identified gait stability worsening from 2 wk to 1 month postinjury in a group of collegiate athletes who each returned to their sport within 2 wk of injury despite not reporting a second concussion (23). Other studies have concluded that traditional methods used to determine RTA timing may not possess sufficient sensitivity to detect concussion-related abnormalities that persist beyond symptom or clinical resolution (25,30). Thus, returning to activity when recovery is not complete may exacerbate deficits related to incomplete recovery and may result in the worsening of frontal plane motion control observed during dual-task walking.

Limitations. The potential variability among healthcare professionals in assessing concussion recovery possibly influenced the timing of RTA. Although current best practice indicates a period of cognitive rest after concussion (22), which has been shown to be effective in decreasing the time required to achieve symptom recovery (4), the amount of cognitive activity each participant was exposed to after injury is unknown.

CONCLUSION

After the RTA after concussion, adolescents with concussion displayed increased medial/lateral COM displacement and velocity during dual-task walking, suggesting a regression of recovery in gait balance control. This study reinforces the need for a multifaceted approach to concussion management and continued monitoring beyond the point of clinical recovery and the resumption of physical activities.

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The authors declare no conflicts of interest.

The results of the present study do not constitute an endorsement by the American College of Sports Medicine.