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The Effects of a Single Bout of Soccer Heading on Single and Dual-Task Gait in Collegiate Recreationally Active Individuals

KARLEE BURNS, MS ATC[1]; MADISON LOHR, MS, ATC[1], JANE MCDEVITT, PHD, ATC, CSCS[2]
[1]Department of Kinesiology, College of Public Health, Temple University
[2]Department of Health and Rehabilitation Sciences, College of Public Health, Temple University

Correspondence: jane.mcdevitt@temple.edu (Jane McDevitt).

***Introduction**: The understanding of subconcussive impacts is limited, with few assessments to determine effects in a recreationally active population due to existing tests being static and unidimensional. **Methods**: This study investigated the effects of 10 soccer headers on pre and post-test measurements of patient reported outcome measures and single and dual-task tandem gait of 12 recreationally active college-aged participants. **Results**: No changes due to the heading session were observed; however, there was a detectable learning effect with participants walking faster and committing more gait errors but less cognitive errors. **Conclusion**: A bout of soccer heading may not pose an immediate risk to dynamic postural control and cognitive function.*

***Keywords**: Concussion, Subconcussion, Assessment, Cognition*

Introduction

Repetitive head impacts (RHI) are mild impacts that do not result in concussion symptoms or diagnosis.[1] Research investigating the outcomes of RHI in athletes has identified negative cognitive and neuropathological effects, though identifying the subtle functional impairments that transpire are difficult, resulting in conflicting reports.[2-6] Given the frequency of RHI in sport, the public health implications of these effects may be significant.

RHI are common in soccer, where excess heading of the soccer ball,[7] may result in subclinical problems, which were not explained with a history of a concussion diagnosis.[8] Further, soccer players that head the ball more frequently reported higher symptom scores.[2] Having dynamic, functional, and sensitive measures to assess the effects of RHI would be beneficial.[9]

There have been several investigations using different concussion assessments to identify the effects resulting from RHIs following soccer headings. Cognitive exams revealed decreased voluntary control and slower reaction times[4,6] and after 10 soccer headings, the effects of RHI were observed in the oculomotor system with near point of convergence measures changing.[10] Negative cognitive and oculomotor changes are indicative of poor health outcomes. However, acute and cumulative effects of soccer heading using balance assessments have conflicting findings (e.g., are postural control deficits present).[5,6] Many of the balance assessments employed were static measures and may not engage the functionality that is necessary for an athletic population.[9]

The single and dual-task tandem gait assessments are used to evaluate dynamic balance and have an 80% sensitivity in identifying effects of concussion two weeks post injury.[12,13] In single-task tandem gait, multiple systems are required to coordinate and execute this movement, which is more demonstrative of the skills required of athletes; therefore, this type of assessment is more applicable than a static balance measure.[14] Dual-task assessments pair dynamic postural control with a cognitive task to further challenge the individual.[14]

With the various clinician-based outcomes (e.g., balance, cognitive testing) currently in use, implementing validated patient reported outcome measures (PROM) like the Disablement in Physically Active Scale (DPAS) and Post-Concussion Symptom Scale (PCSS) could be beneficial in determining if the athlete themselves identifies any changes. Though specific questionnaires for concussion and subconcussion have not yet been developed, the DPAS and PCSS can identify functional limitations, impairments, quality of life changes in physically active individuals.[15-17] If signs are symptoms (e.g., PCSS) are reported after a head impact, clinicians should further evaluate for concussion.

Changes in self-reported symptoms after an acute soccer heading model have been identified; however, functional details and PROMs were not reported.[16] Further, dynamic changes have been found following concussion[12] or after an acute bout of soccer heading,[11] but needed expensive laboratory equipment and lacked details regarding how the athlete believes they are being affected by the RHIs. Therefore, the purpose of this study was to investigate the effects of RHIs from an acute bout of soccer headings on single and dual-task tandem gait tasks and PROMs in recreationally active college-aged individuals.

Methods

Participants

Twelve collegiate students volunteered to participate in the study. Individuals were eligible to participate if they self-reported they were healthy, aged 18 years or older, and had five or more years of lifetime soccer heading experience. Individuals were excluded if they had self-reported abnormal gait deficits, concussion or lower extremity injury in the previous 6 months, or vestibulo-ocular dysfunctions (e.g., inner ear infection, vertigo). This study was approved by Temple University's Institutional Review Board and participants signed an approved consent form prior to data collection.

Instrumentation

Patient Reported Outcome Measures

The Post-Concussion Symptom Scale (PCSS) consists of 22 symptoms rated on a scale of 0 (i.e., not experiencing) to 6 (i.e., most severe). Total severity score was determined by adding each of the 22 ratings.[17] The DPAS assesses the physical ability of patients (e.g., changing directions, overall fitness). The scale consists of 16 questions rated from 0 (i.e., no problem) to 4 (i.e., the problem severely affects the patient).[18]

Accelerometer

A triaxial accelerometer was affixed with a headband (G Force Trackers, Richmond Hill, Ontario) and placed on the participant's occiput to measure head kinematics (i.e., linear and rotational acceleration) during the soccer header.[19]

Tasks

Single-Task Tandem Gait

The participants were instructed to walk along a 3m strip of tape in a heel-to-toe fashion with hands on hips to the end of the tape, turn 180°, and return in the same heel-to-toe fashion completely past the original starting point of the tape. Each participant was informed on what an error was (i.e., heel does not meet toe, steps off tape, takes hands off hips). To streamline data collection and for ease of clinical application all participants completed one practice trial and two measured trials for the pre-test and three trials post-test.[20,21] In addition to trial time and tandem gait errors, additional gait outcome measurements (e.g., cadence) were included in this study. These outcomes were chosen for their clinical application and prior inclusion in gait and concussion literature.[22] All trials were video recorded for post-processing.[6]

Dual Task Tandem Gait

This gait assessment was performed in the same manner as the single-task gait assessment with the inclusion of a cognitive task. For the cognitive task, a 5-letter word, based on 5th grade comprehension, was spelled backwards from a list of 40. Cognitive errors included if the word was spelled incorrectly or the participant stated they were unsure after attempting the word (e.g., "pass"). One attempt at spelling was given and then the next word was read off until the test was completed. Different words were used for all trials.[23] Number of dual-task tandem gait trials were consistent with single-task trials.

Soccer Heading Model

A controlled soccer heading paradigm in a laboratory was used as described by Tierney and colleagues.[24] This soccer heading paradigm serves as a functional *in vivo* head impact testing model, which can be used to elucidate mechanisms underlying individual responses to head impact in soccer.[24] A JUGS Soccer Machine (JPS Sports International, Tualatin, OR, USA) launched a standard adult size 5, inflated to full regulation 8 psi, at an angle of approximately 40° and with an initial projection velocity of 25 mph, confirmed via radar gun, to simulate a soccer throw in. After a warm-up with a foam ball, each participant in the experimental group performed 10 headers with a minute of rest in between each header. Two mistrials (e.g., missing ball, ball hitting top of the head) were allowed per participant. The control group sat for 10 mins to simulate the duration of the heading model while limiting movement.

Procedures

Participants completed the health history questionnaire, pre-test PCSS, DPAS, and single and dual-task trials and were fitted with the accelerometer. Participants completed the heading model for their randomly assigned group (determined by coin flip at study inception). Participants were blinded to group assignment until the heading phase of data collection. Following the heading model, participants completed the post-test measurements.

Statistical Analysis

Descriptive and inferential statistics were calculated to evaluate data. Averages from both gait trials were included as dependent variables: time (s), steps, gait errors, and cadence (steps/minute). Dual-task tandem gait dependent variables also included cognitive errors.

To determine the effect of heading group on PROMs and single and dual-task tandem gait parameters three repeated measure MANOVAs were utilized: one for each set of conceptually related and correlated variables, where F value was determined using Pillai's. Trace. Bivariate Pearson Correlations were performed between the dependent variables and the average of linear and rotational acceleration to determine associations between performance and head kinematics. SPSS version 26.0 (SPSS IBM Inc. Armonk, NY) was used for all analyses, with alpha level $p \leq 0.05$.

Results

Participants

Participant descriptive data are presented in Table 1. Post-hoc power analysis of the sample size was approximately 0.50.[25] At pre-test there were no significant differences between groups. The mean 13.5 years of soccer heading experience was above the minimum of five years.

Table 1.
Participant Demographics

		Group[a]		Statistic	
Variable	Total (n=12)	Heading (n=6)	Control (n=6)	*p*-value	Effect size[b]
Male	7	4	3	.54	.31
Age (years)	19.62 (3.97)	21.83 (1.94)	22.33 (2.34)	.38	.23
Experience (years)	13.50 (2.8)	14.83 (2.04)	12.17 (3.06)	.69	.95

Note. Age and Experience expressed as Mean (SD)).
a Participants randomly assigned to heading and control groups.
b Effect size benchmarks based on Cohen: Small = .2, medium = .5, large = .8

Patient Reported Outcome Measures

Means ± standard deviation (SD) for pre-test and post-test for each PROM are reported in Table 2. The MANOVA revealed a main effect for test (F = 5.650; p = 0.039). Specifically, there was a significant interaction between time and group, where the heading group scored higher (i.e., more symptomatic) on the PCSS and lower (i.e., better) on the DPAS compared to the control group, p = 0.042, η^2 = 0.35.

Table 2
Participant Reported Outcome Score by Time and Group

Variable	Group[a] Heading (n=6)	Group[a] Control (n=6)
Pre-Test PCSS	3.67 (4.03)	0.17 (0.41)
Post-Test PCSS	2.33 (4.41)	2.00 (2.10)
Pre-Test DPAS	9.33 (8.24)	1.33 (1.97)
Post-Test DPAS	7.00 (7.95)	2.17 (2.64)

Note. Variable scores expressed as Mean (SD)).
Abbreviation: PCSS, Post-Concussion Symptom Scale, DPAS, Disablement in the Physically Active Scale
a Participants randomly assigned to heading and control groups.

Single-Task Tandem Gait

Pre-test and post-test single-task tandem gait parameter measurements are presented in Table 3. The MANOVA revealed a significant main effect for time (F = 7.765; p = 0.019) and test (F = 945.641; p = 0.000). Specifically, there was an interaction between tests and time, p = 0.030, η^2 = 0.65, where participants executed the task quicker, with more errors and using a faster cadence during post-test. There were no group main effects or interactions, p = 0.820.

Table 3
Single-Task Tandem Gait Parameters by Time and Group

Variable	Group[a] Heading (n=6)	Group[a] Control (n=6)
Pre-Test Time	18.24 (2.68)	18.37 (3.08)
Post-Test Time	16.93 (1.65)	17.58 (2.46)
Pre-Test Error	5.67 (1.13)	4.67 (2.67)
Post-Test Error	6.83 (2.30)	5.00 (2.33)
Pre-Test Steps	23.09 (1.29)	22.83 (2.40)
Post-Test Steps	22.94 (1.32)	22.89 (2.32)
Pre-Test Cadence	77.47 (12.40)	76.43 (16.60)
Post-Test Cadence	82.38 (11.04)	79.56 (15.30)

Note. Variable scores expressed as Mean (SD)). Time (s), cadence reported in steps per minute.
a Participants randomly assigned to heading and control groups.

Dual-Task Tandem Gait

Pre- and post-test dual-task tandem gait measurements are conveyed in Table 4. The MANOVA conveyed a significant main effect for time (F = 5.614, p = 0.039, η^2 = 0.360) and test (F = 3611.129, p = 0.000, η^2 = 1.000). Specifically, gait errors increased, cognitive errors decreased, and cadence increased at post-test. There were no group main effects or interactions, p = 0.444.

Table 4.
Dual-Task Tandem Gait Parameters by Time and Group

	Group[a]	
Variable	Heading (n=6)	Control (n=6)
Pre-Test Time	21.34 (3.33)	22.50 (4.39)
Post-Test Time	20.53 (3.21)	20.68 (4.69)
Pre-Test Error	6.33 (1.63)	4.58 (2.58)
Post-Test Error	5.88 (2.25)	6.22 (2.55)
Pre-Test Cognitive Error	0.75 (0.42)	1.08 (.06)
Post-Test Cognitive Error	0.99 (0.57)	1.00 (.079)
Pre-Test Steps	23.00 (1.38)	22.67 (2.44)
Post-Test Steps	22.94 (1.46)	22.67 (2.57)
Pre-Test Cadence	66.10 (11.54)	64.52 (13.60)
Post-Test Cadence	68.30 (10.92)	69.15 (19.47)

Note. Variable scores expressed as Mean (SD)). Time (s), cadence reported in steps per minute.
a Participants randomly assigned to heading and control groups.

Heading Kinematics

Linear acceleration had a mean of 18.57 ± 2.18g and the rotational acceleration mean was 815.24 ± 147.71°/s². Missing accelerometer data for one participant was filled using the series mean. Significant correlations were found for rotational acceleration and PCSS (r = 0.931, p = 0.007), rotational acceleration and DPAS (r = 0.815, p = 0.048), and linear acceleration and dual-task step (r = 0.891, p = 0.017). Each was a positive correlation whereas head kinematics increased, PROM score and steps increased.

Discussion

The purpose of this study was to assess the effects of an acute bout of soccer headings on single and dual-task tandem gait and PROMs. This study was novel due to the low threshold of impacts measured in a healthy non-concussed population. Our findings suggest that 10 soccer headers resembling a soccer throw in were not sufficient to invoke acute symptomatology or affect either gait assessment, in agreement with previous research.[26] However, there appears to be a learning curve with both heading and control groups beginning to complete the task faster with quicker cadence and compensating by committing more errors. These same changes were also seen in the dual-task assessment with cognitive errors also decreasing further suggesting a learning effect occurred.

Linear and rotational acceleration means were similar to those recorded during games and practices of collegiate soccer players.[27] The strong positive significant correlations between symptom score (i.e., PCSS, DPAS) and rotational acceleration indicate headers with increased rotational acceleration are reporting more symptoms after the heading session. Angular acceleration, more so than linear acceleration, has been identified as more damaging to the brain, causing shearing deformation and greater physiological changes throughout the brain.[28]

In the PROM pre and post-test scores, there were no significant differences between groups. There was one score approximately two standard deviations above the mean for all four PROMs (i.e., pre- and post-test PCSS and DPAS) that was kept in the data set. This may help explain the large variability between heading and control groups.

Clinical Implications

The current study suggests that single and dual-task tandem gait measures that are easily assessed by a clinician are not affected by an acute bout of a laboratory-controlled session of soccer heading. Tandem gait assessments have been used to identify lingering effects of concussion up to 2 weeks post-injury and the cumulative effects of a season.[6,12] While our study found no significant deficits after 10 headers, following a concussive event the dynamic postural changes are greater and result in prolonged deficits that can be measured using single and dual-task tandem gait.[6]

Previous researchers have identified different effects of RHI.[4,7,8,] Negative cognitive changes after a practice involving soccer heading were identified using a tablet-based application.[7] A similar study over the course of a season showed changes in cognitive scores of an n-back task.[29] Though the findings contributed to the understanding of the effects of RHI, they were limited by the use of technology and lack of a functional aspect making it difficult to translate to a clinical or sideline assessment and to an active population. The current study utilized a functional (i.e., gait) and cognitive measure (i.e., backwards spelling) providing a more comparable assessment for an athletic population due to the increased complexity and real-world applicability (e.g., multi-tasking) and found that there were no performance deficits (e.g., slowed tandem gait) or PROMs (e.g., worsening DPAS scores) reported following the acute bout of purposeful soccer heading.

Limitations

It is important to note some limitations of this study. A learning effect seemed to occur with participants starting to walk faster by committing more gait errors. External validity was limited since this study was performed in a controlled environment and may not be applicable for the sideline where there may be other distractions. Additionally, the ball was projected at a relatively slow speed (e.g., throw in). Additionally, lack of deficits in symptomatology, balance, and cognitive abilities could be attributed to the overall low acceleration the ball was projected as compared to if the ball were to be projected at larger acceleration loads (e.g., goal kick). Lastly, this study utilized a small, set window of RHI to replicate a single practice session.

Future Research

Focus of future research should be on functional and translational assessments as well as include field studies to determine the efficacy of performance on the sideline. Additionally, more attention should be on the effects of RHI over a longer time frame such as the course of a season with variable accelerations similar to those seen during a game and/or practice.

Conclusion

In conclusion, RHI did not affect PROMs or single and dual-task tandem gait parameters following an acute bout of purposeful soccer headings. Athletic trainers should be aware that a small, acute bout of RHI may pose little risk to patients. Long-term exposure to RHI and/or larger head accelerations may affect cognitive performance and dynamic postural control. When considering assessment of these potential effects, single and dual-task tandem gait may be a sensitive enough measurement; however, further research surrounding acute and long-term heading still needs to be conducted.

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Conflicts of Interest
The authors have no conflicts of interest to report.

Statement of Contributions
K.B. and M.L. carried out the study, analysis of results, and wrote the manuscript. J.M. contributed to the interpretation of results, the final version of the manuscript, and supervised the project.

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