Sports-related concussions are becoming a public health issue in both recreational and organized sports. One important aspect of this issue is the effect of subconcussive blows – impacts to the head that do not cause a concussion, but may have physiological and behavioral effects that can accumulate over time. There is conflicting information about the safety of heading by soccer players because of the potential deleterious effects of accumulated subconcussive blows, but it has not been well-documented, specifically in female soccer player.

There is much more research on the effects of multiple concussions. Recent research suggests potentially severe long-term effects of multiple concussions, including increased risk of developing neurodegenerative diseases (e.g., Alzheimer's disease, Parkinsonism) especially with loss of consciousness accompanying concussion (Bazarian, Cernak, Noble-Haeusslein, Potolicchio & Temkin, 2009; Chen, Richard, Sandler, Umbach, & Kamel, 2007). Additionally, athletes with previous concussions participating in both helmeted and un-helmeted sports also reported more symptoms during baseline testing, specifically headache, memory problems, and an overall "slowness", and they experienced more severe symptoms in the acute stage of a concussion (Iverson, Gaetz, Lovell, & Collins, 2004).

While some evidence indicates that soccer participation poses no greater risk for neurocognitive impairment than participation in other contact and non-contact sports at the youth level (Rutherford, Stephens, Potter & Fernie, 2005), research at the collegiate level comparing soccer players to non-contact and contact controls indicated a relationship between increased exposure to heading and poorer performance on neuropsychological tests (Matser, Kessels, Lezak, Jordan & Troost, 1999). Also, when compared with non-athlete controls and players who self-identified as infrequent headers, soccer players who self-identified as frequent headers performed significantly worse on neuropsychological tests (Witol & Webbe, 2003).

The aim of the current study was to examine the relationship between number of headers and cognitive processing in collegiate female soccer players over the course of a typical soccer season. This study expands upon the current literature by counting headers not only during games, but also during practices. Additionally, cognitive function was assessed at 4 points throughout the season to allow examination of change over time. The primary hypothesis was that performance on a cognitive test would be negatively related to the number of headers during the season.

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Procedures

Participants

There were 14 participants from the Rice women's soccer team. All were between age 18 and 23, female, and enrolled at Rice University. Only females were included to create a homogeneous group for this relatively small study because previous research suggests headers affect females more than males (Tierney et al., 2008). Collegiate athletes were selected because they are closely monitored and receive standard care for suspected concussions. Participants were all concussion-free for at least 6 months to minimize the chance that they had lingering cognitive effects from a previous concussion, as well as the chance that a sub-concussive blow would result in dramatic changes in cognitive function. See Table 1 for demographic and clinical data.

Methods

Participants completed the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT; Iverson, Lovell, & Collins, 2005; Lovell, et al., 2006) four times during the 2012-2013 season times (baseline, mid-season, immediate post-season, delayed post-season). The ImPACT testing is routinely used as a pre-season baseline measure of cognitive function, and is used to assess and monitor recovery in athletes who incur a concussion. Scores from the ImPACT include symptom score, subtest scores and 5 composite scores: Verbal Memory Composite, Visual Memory Composite, Visual Motor Composite, Reaction Time Composite, and Impulse Control Composite ("About ImPACT," 2012). Examples of tasks include word discrimination, symbol and color matching, and three letter memory. Composite scores are derived from a combination of scores on different tasks. For example, the Verbal Memory Composite score is comprised of the average of the total memory percent correct, symbol matching, and three-letter memory scores. The ImPACT was administered in a computer lab on the Rice campus per standard procedures set by Rice Athletics. The fourth administration will be completed by the end of January 2013.

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A subset of practices and approximately 30% of games were observed and videotaped to count the number of headers for each participant. The videos were reviewed and the time and number of headers per player were recorded. Reliability of header counts will be assessed by having the second author review a minimum of 10% of the videos.

Results

To date, preliminary analyses have been conducted using the header counts and three composite scores (verbal memory, visual memory, and visual-motor) from first three test administrations (see Table 1). To assess change in cognitive function over the course of the season, 2-tailed paired sample t-tests were conducted on baseline and end-of-season ImPACT composite scores. No significant difference was obtained on the Verbal Memory Composite score $t(13)=1.265$, $p = .228$ or the Visual Memory Composite score $t(13)=1.438$, $p = .174$. There was a significant increase from baseline to end-of-season on the Visual-Motor Composite score $t(13)=3.294$, $p = .006$.

To assess potential group differences related to the number of headers, participants were assigned to a no header, medium header, or high header group based on the total number of headers observed in games and practices combined. Visual inspection of the data revealed three clearly distinct groups (no header = 0, medium header = 17-28, high header = 53+). Difference scores for the ImPACT composites were calculated by subtracting the end-of-season scores from the baseline scores. Due to the small number of participants in each subgroup, nonparametric independent sample median tests were conducted examine group differences No significant differences were observed on the Verbal Memory Composite score ($p = 1.000$), Visual Memory Composite score ($p = .097$), or the Visual Motor Composite Score ($p = .368$). High variability was noted in the high header group for both Visual Memory and Visual-Motor Speed Composite scores.

Discussion

The results from the preliminary analyses did not support the hypothesis. There were no negative changes in cognitive function across the soccer season for the athletes as a group. The increase in visual-motor performance may indicate that the athletes under-performed on the test during the baseline assessment. This practice of underperforming has been widely discussed in the sports concussion literature (e.g., Bailey, Echemendia, & Arnett, 2006) although there are measures built into the ImPACT program to flag scores that appear to reveal inadequate effort.

The lack of significant differences in cognitive performance across the header sub-groups was unexpected. However, the subgroups were small (only 3-4 participants per group), and the high-header group evidenced highly variable performance on the visuomotor tasks. Both of these factors contribute to lowering the power of the analyses. Another explanation is that the blows incurred by headers did not, over the course of a soccer season, have a measurable impact on cognitive performance as measured by the ImPACT test.

Further analyses will be conducted to examine patterns of cognitive performance across the season and will include the other composite scores as well as the symptom scores

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Conclusions

This study expands upon the current state of knowledge by testing cognitive function at multiple points throughout the soccer season, and counting headers not only in games, but also during soccer practices. Further research with larger groups is needed to elucidate the effects of repeated heading on cognitive function in collegiate female athletes.

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Table 1. Demographic and clinical data for 14 female participants

	Mean (S.D)	Range
Age	19.07 (1.328)	18-22
Years of education	13.00 (1.177)	11-15
Number of years playing collegiate soccer	1.08 (1.256)	0-3
Number of diagnosed concussions	0.36 (0.845)	0-3
Number of headers		
Entire team	22.64	0-67
High header group	59.25	53-67
Moderate header group	23.33	17-28
No header group	0.00	0-0
ImPACT scores		
Verbal memory composite		
Baseline	88.93 (8.398)	73-100
Mid-Season	93.36 (8.025)	71-100
End-of-Season	92.36 (8.130)	72-100
Visual memory composite		
Baseline	75.71 (17.407)	45-100
Mid-Season	83.71 (16.578)	33-100
End-of-Season	82.07 (12.976)	55-100
Visual Motor composite		
Baseline	43.97 (5.80)	27.83-50.95
Mid-Season	44.45 (7.10)	28.85-51.68
End-of-Season	46.52 (5.71)	32.75-52.47