

# The Epidemiology of Soccer Heading in Competitive Youth Players

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We administered neurocognitive batteries to 49 youth soccer athletes (9–15 yr), who were selected from competitive soccer teams in Central Florida. We collected observational data on soccer heading, self-reported soccer heading, as well as demographics, including school, medical, and soccer history. Both the frequency and intensity of heading the ball in soccer was low in comparison with adolescents and adults. In our sample, the vast majority of soccer headings were of low to moderate intensity and direct (i.e., the incoming flight of the ball was perpendicular to the forehead). Age significantly correlated with frequent heading. Parents were reliable observers of their children's soccer heading behavior and other at-risk behaviors during games. The majority of soccer headings were direct rather than flicks. Almost half of our participants reported headache and one-fourth reported dizziness after instances of heading the ball. Frequency of soccer heading was not related to neuropsychological score data.

Soccer is the most widely played team sport in the world. In the United States alone, an estimated 13 million children under the age of 18 play soccer (American Academy of Pediatrics, 2000; Schwebel, Banaszek, & McDaniel, 2007). In 2005, nearly 30% of children under the age of 12 participated in soccer. Although soccer has frequently been marketed as a safe alternative to football, the actual injury rate is not much lower, and the head injury rate accounts for 4.9–22% of soccer injuries in adolescents (American Academy of Pediatrics, 2000). Understanding injury dynamics requires attention to normal playing characteristics, as well as appreciation of style of play, position played, and amount of time actually engaged in play. As such, the present goal is to consider soccer play related to ball heading since that behavior places athletes at greater risk of head injury. The data presented are based upon analysis of the first year of a five-year longitudinal study. We believe it is important to show the preliminary data since the data provide evidence that heading in youth soccer may be a minimal risk factor for head injuries.

## Sports-Related Head Injuries: Prevalence and Incidence

Participation in sport involves a risk for injuries, including head injuries. Previous studies show that high school athletes sustain concussions at a higher rate than collegiate athletes participating in the same sport (Barth et al., 1989; Guskiewicz, Weaver, Padua, & Garrett, 2000). Boys have a higher frequency of injury than girls do with the same amount of athletic exposure (American Academy of Pediatrics, 2000). According to McKeever and Schatz (2003), reports of sports-related concussion appear to be on the rise due to increased vigilance, the greater number of years that athletes engage in sports, the total sports activities of the youth athlete, as well as the overall higher level of athletic participation. Although sports concussion research with adults and professional athletes has become prominent in recent decades, collection of reliable sports concussion data with children remains in its infancy. Moreover, the reported incidence of sport related concussion for adolescents and adults probably underestimates the actual numbers for three reasons: (a) fear of losing one's position (Delaney, Lacroix, Leclerc, & Johnston, 2002), (b) high motivation to return-to-play (Lovell & Collins, 1998), and (c) a general lack of awareness of concussion symptoms by players and those responsible for treating them (McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004). Children are even more likely to lack awareness of concussion symptoms and so may not accurately report their symptoms. Without knowledge of such critical information about their child's symptoms, parents may not understand that these injuries require medical attention. The likelihood that a trained professional will be in attendance at youth competitions is low. Indeed, professional medical or trainer support varies inversely with the level of competition extending down from professional, to college, to high school, and finally to youth (Moser et al., 2007). Therefore, injuries may occur and may not be properly identified by coaches and parents.

### Mechanism of Head Injuries and Soccer Heading

Overall, the most common criteria for determining concussion include a Glasgow Coma Score (GCS) of 13–15, no loss of consciousness (LOC), no prolonged period of posttraumatic amnesia (PTA), and an immediate but transient impairment of neural function (Bailes & Cantu, 2001). Although a magnet for attention and medical referral, LOC is not always indicative of concussions (Cantu, 2001). Therefore, in the absence of LOC, sport-related concussion in children may not be assessed accurately. At the present time, there is no grading system that emphasizes an evidence-based approach toward identification of concussion in the child athlete.

In soccer play, concussive head injuries are most likely to happen when two players make a mutual attempt to head the ball. Heads banging together or elbows and fists striking a head are common. Less common are injuries related to the ball striking the head. Intentional heading may be direct—that is the ball is redirected back in the same flight path, perpendicular to the forehead. Heading also may be indirect or “flicked,” that is the head redirects the ball at an angle to its previous

flight path. Flicks often require turning of the head, which contributes rotational acceleration to the head and brain.

## Developmental Issues

In the past, it was thought that greater plasticity in the developing brain would produce more rapid and complete recovery following brain injury. More recent evidence suggests that injury severity and age correlate negatively in predicting recovery (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005). At least three factors contribute to an increased susceptibility to concussion in children as compared with adults: (a) incomplete myelination of brain axons, resulting in greater water to tissue ratios and less compressibility of tissue; (b) a greater head-to-body ratio; and (c) thinner cranial bones, which provide less protection to the developing cortex (McKeever & Schatz 2003). This vulnerability may lead to worse neuropsychological outcomes for children who sustain mild head injuries, including concussion. Ewing-Cobbs et al. (1997) assert that young children may be at particularly increased risk for poor long-term neurobehavioral outcomes because of the way an injury can interfere with emerging or rapidly developing skills. Moser and Schatz (2002) observed that high school athletes (aged 14–19) had longer lasting somatic and neurocognitive symptoms than expected in comparison with prior research with older athletes.

Other evidence suggests that head injuries and neck injuries *increase* as a function of increasing age (Proctor & Cantu, 2000), possibly due to a greater intensity of physical effort. Although the consequences of concussion on the developing brain are still not clearly defined, there are three reasons that it is important to be conservative when making return-to-play decisions in child athletes: (a) Children who do not have sufficient time to resolve their symptoms before continuing to play may be at risk for a second injury, including the rare second-impact syndrome, a catastrophic outcome following two closely (temporally) spaced mild concussions. The morbidity of SIS has been linked both to rapid increases in intracranial pressure due to loss of autoregulation of the brain's blood supply (Cantu, 1998) and to dysregulation of metabolic supply from demands following brain injury (Giza & Hovda, 2001). Evidence continues to support that concussion history is an important predictor of concussion incidence (Delaney et al., 2002; Schulz et al., 2004). (b) The cost to youth athletes sitting out of games is lower than to professional athletes while the aftermath of concussion may be higher. Multiple concussions may negatively impact a child athlete's learning, behavior, and school performance, which are critical to their overall functioning and development into adulthood. (c) Youth athletes have the potential to continue playing in competitive sports for many years. An emphasis on the safety of young athletes may support continued athletic participation into college and beyond.

## Head Injury Specific to Soccer

According to Delaney et al. (2002), 62.7% of university soccer players reported symptoms of concussion stemming from play in the previous year. The phenomenon that a history of concussion predisposes an individual to future concussions

has been noted repeatedly, with studies estimating variously that football and soccer players who suffered one concussion in a season were 3–6 times more likely to suffer a second concussion than a player who had no history (Gerberich, Priest, Boen, Straub, & Maxwell, 1983; Guskiewicz, Weaver, Padua, & Garrett, 2000). This relationship figures prominently in arguments for caution in releasing athletes to play and practice (Cantu, 2001; Moser et al., 2007) and highlights the importance of obtaining a thorough history when conducting a neuropsychological assessment with each athlete, including a child.

Within the adult literature, soccer has received increased attention in large part due to reports of the risk of injury when heading the ball (Babbs, 2000; Matser, Kessels, Lezak, & Troost, 2001). This is noteworthy, as Tysvaer and Storli (1981) estimated that professional soccer players may head the ball 2,000 times in 300 career games. There are no clear data related to the frequency of soccer heading that players engage in while at practice. The lack of experience and competence that children may have with heading the soccer ball using proper technique combined with their weaker neck musculature and smaller body mass potentially may make them more vulnerable to sustaining head injuries. The impact of cumulative soccer heading on the brains of children is still not clearly understood, but Schneider and Zernicke (1988) assert that youth soccer players are at greater risk of concussion when their heads are accelerated in an angular movement when striking an oncoming ball.

The recent literature on soccer heading behavior has focused on the amount of accelerative forces needed for an individual to sustain a concussion (200g) as well as the difference of impact between direct vs. rotational force. Naunheim, Standeven, Richter, and Lewis (2000) used helmet-mounted accelerometers to measure the forces associated with contact to the head in soccer, football, and ice hockey in adults. They found that peak accelerations were the greatest for soccer than in American football and hockey. Although peak accelerations in children's heading may not approach adult levels, children may still be at risk for several reasons: (a) not being prepared, (b) less skill that may lead to improper technique, and (c) less neck musculature that could cause injury.

## **Soccer Heading Among Youth Players**

The epidemiology of soccer heading in youth athletes has only recently started receiving attention. Janda, Bir, and Cheney (2002) reported on the frequency of heading in 57 youth soccer players aged 10–13 (20 females and 37 males) across fall, winter, and spring soccer seasons. They also conducted a one-year follow up with 10 boys. They reported an average of 33.75 total headers made by girls in approximately 60 games and/or practices. During the same amount of athletic exposure, boys averaged 131.78 total headers. They did not find a significant relationship between soccer heading frequency and cognitive testing data. They also obtained self-reported symptoms experienced after heading the ball. Notably, Janda et al. (2002) observed that 49.1% of their sample reported headache, 12.3% reported ringing in the ears, 7% reported nausea, and 5.3% reported blurred vision after engaging in soccer heading.

Although Janda et al. (2002) provided much useful information on soccer heading frequency and potential cumulative effects of soccer heading in youth,

there were significant limitations to their report. They did not report on the intensity or type of headers (i.e., direct or flick), which is important as angular and linear forces impact the brain differently and could each have a unique potential for mild head injury in children. They also included practice heading with game heading for their overall measure, even though practice heading may be of considerable less intensity than game heading. Furthermore, they did not analyze soccer heading frequency by position or comment on personal/organismic factors related to heading. Indeed, the basic question of how many times players headed the ball could not be easily seen in their data. They also did not obtain a baseline of symptoms before heading the ball, which would lead to a clearer understanding of the impact of heading on children. In fact, several studies have shown that postconcussive symptoms are reported in the population without the presence of injury (Chan, 2001). Finally, Janda et al. (2002) did not obtain a history of each athlete related to school grades, premorbid learning difficulties, as well as extent of athletic participation, which are important in accurately determining outcome of cognitive assessments as well as interpreting factors related to soccer heading behavior. Given these limitations and the general dearth of information on the incidence of soccer heading, additional studies need to be conducted with children before deciding whether these young athletes are at risk for neurocognitive impairment due to soccer heading. Because most concussions occurring within soccer are associated with heading (usually from banging of heads or other head collisions; Kirkendall, Jordan, & Garrett, 2001), and since the effect of repetitive subconcussive head impacts due to heading the ball is not yet well understood, this lack of inquiry is surprising. As soccer continues to become more competitive at younger ages, more children still in critical stages of development are exposed to head injury risk. Recent studies also suggest that concussion-related research in children should focus on premorbid neurocognitive functioning (Donders & Strom, 1997); however, children with premorbid learning problems are often omitted from studies despite being more vulnerable to persistent postconcussive symptoms. Specifically, children with ADHD and learning disorders may be more vulnerable to mild traumatic brain injury (mTBI) and soccer heading due to preexisting deficits. Moreover, the entire issue of repetitive impacts causing cumulative damage is rarely addressed despite the common report of concussion-like symptoms following heading events (Barnes et al., 1998; Webbe & Ochs, 2003).

## Purpose

Repetitive heading impacts and subconcussive blows to the head may lead to neurocognitive impairment in some soccer athletes. There are no clear data on the frequency of heading in youth soccer and whether heading leads to neurocognitive impairment. Before understanding the potential impact of heading on the developing brain, it is critical first to understand the incidence of soccer heading within the context of the youth game. One purpose of this longitudinal study was to obtain epidemiological information of soccer heading behavior in elementary and middle school aged male and female soccer players as well as to relate heading behavior to physical and psychological symptom reports and neurocognitive performance. Due to the inaccuracy of self-reported heading frequency in adults,

we compare direct observations of heading versus self-report from the first year of the study, using parents as observers of their children in games. The object of this early report is to provide needed information not only on epidemiology but on neurocognitive correlates in children. We also provide recommendations for monitoring all head impacts and safe approaches to heading the ball in youth soccer based on our findings and a review of the sports literature.

## Method

### Participants

Forty-nine youth soccer athletes were recruited from competitive soccer teams in Central Florida. Our focus was on children who played soccer competitively, because they represented the youth population most likely to engage in frequent heading behavior. Participants were recruited through newspaper publicity, e-mail, and distribution of brochures at soccer camps, practices, games, tournaments, and direct contacts with competitive team coaches. Table 1 outlines the demographics of the 49 children in the sample. Twenty-two girls and 27 boys comprised the sample, with a mean age of 12.16 ( $SD = 1.56$ ). The mean grade level was 6.98 ( $SD = 1.42$ ), and all but one child were high academic achievers with either an A or B

**Table 1 Demographic Data for Participants**

Variable	Frequency	Percent	Mean	SD
Age			12.16	
Gender				
Girls	22	44.9		
Boys	27	55.1		
Race				
Caucasian	47	95.9		
African American	1	2.0		
Hispanic	1	2.0		
Handedness				
Right	44	89.8		
Left	5	10.2		
School Grades				
A average	32	65.3		
B average	16	32.7		
C average	1	2.0		
WISC-IV			11.71	2.18
Vocabulary				
WISC-IV Block			10.37	2.42
Design				
History	6	12.2		
Concussion				

grade average. This school performance was mirrored in the WISC-IV Vocabulary and Block Design averages, which were in the normal range. In terms of soccer experience, the vast majority of the athletes were starters on their teams and 75% reported that they played at least three-fourths of most games. All positions on the field were represented, and players averaged 3.14 years ( $SD = 1.88$ ) of playing competitive soccer. Soccer-specific information is shown in Table 2.

## Measures

Following IRB approval and informed consent from both the parent and child, all children completed a questionnaire, followed by a battery of tests, including the Children's Concussion Resolution Index (CRI-C, HeadMinder, Inc.), Trail Making Test (TMT) Parts A and B of Rey Auditory Verbal Learning Test (RAVLT), Tower of London (ToL DX), Wechsler Intelligence Scale for Children-IV (WISC-IV) Vocabulary and Block Design subtests, and the Child Behavior Checklist (CBCL).

**Interview and Background Questionnaire.** Each parent and child participated in a 20-minute structured interview during which demographic and personal data also were collected, including school history, medical information and history, LD/ADHD diagnosis, and current medications. We obtained a full soccer playing history, including years of soccer participation, years playing at both recreational and competitive levels, playing time in games, starting status, and position played. The youth players compared their own style of play to that of opponents and team-

**Table 2 Soccer Specific Demographics**

Variable	Frequency	Percent	Mean	SD
Soccer Experience				
Years playing soccer			6.76	2.37
Years playing competitive			3.14	1.88
Starters	40	83.3		
Playing Time in Games				
Whole game	16	33.3		
Three quarters of game	20	41.7		
Half of game	11	22.9		
Less than half game	1	2.1		
Position				
Offense	14	29.8		
Midfield	18	38.3		
Defense	10	21.3		
Goalie	5	10.6		

mates using a 7-point Likert scale that ranged from *much less aggressive* to *much more aggressive*. Regarding soccer heading behavior, children (with the parents' help) estimated the number of times that they headed the ball in practices and games. The players also rated their frequency of heading the ball in comparison with opponents and teammates using a 7-point Likert scale ranging from *much less frequently* to *much more frequently*. We asked each child (and his or her parents) whether he or she had received formal instruction on the proper heading technique and whether he or she engaged in heading drills during practices. Finally, the children completed a checklist of 19 common symptoms of concussion, once for current symptoms, and once for symptoms experienced after heading the ball. Severity of each symptom was also documented.

**Child Behavior Checklist/Ages 6–18 (CBCL/6–18).** The parent version of the CBCL/6–18 (Achenbach & Rescoria, 2001) contains 118 items related to problem behaviors exhibited by their child in the past six months. Recent research indicates that a T-score of 55 on the Attention Problems and the Aggressive Behavior syndromes instead of the T-65 cutoff effectively minimizes false positive and false negatives in the assessment of ADHD (Hudziak, Copeland, Stanger, & Wadsworth, 2004). We used a score of 55 or higher on the CBCL Attention Problems syndrome scale to derive an ADHD probable group in the absence of a formal diagnosis.

**Trail Making Test (TMT) Parts A and B.** This test measures visual scanning and tracking, cognitive flexibility, attention and concentration, as well as psychomotor speed (Reitan, 1955). During Part A, an individual is required to draw lines to connect consecutive numbers in circles, whereas in Part B, the individual alternates between connecting consecutively numbered and lettered circles. Scoring is based on total completion time.

**Key Auditory Learning Test (RAVLT).** This measure is comprised of a 15-item word list (List A) that is presented orally for five trials and requires the individual to recall as many of the words as he or she can for each trial (Rey, 1964). An interference word list (List B) is given after the fifth trial. The individual's recall of List A is assessed immediately following the interference word list and again after a 30-minute delay. The score for each trial is the number of words correctly recalled.

**Tower of London-Drexel University (ToLDX).** This test measures an individual's ability to conceptualize change, respond objectively, generate and select alternatives, and sustain attention (Culbertson & Zillmer, 1998). The examiner places two boards with three different sized pegs in front of the subject and the examiner. Three different colored beads (red, blue, green) are arranged in a pattern on the examiner's board and provide the targeted goal for the subject. The individual must only move one ball at a time and must leave only a specified number of balls on each peg at a time. Ten increasingly difficult problems are given, with two minutes being allowed for each trial. A problem is scored correct if the solution is achieved with the minimum number of moves necessary.

**Weschler Intelligence Scale for Children-IV Vocabulary (VC) Subtest.** The child provides definitions for words that the examiner reads aloud (Weschler, 2003). There are also four picture items for which the child names pictures that

are displayed in the Stimulus Booklet. This test measures word knowledge and language development and was used to estimate verbal IQ.

**Weschler Intelligence Scale for Children-IV Block Design (BD) Subtest.** The child uses red and white blocks to recreate either a constructed model or a picture in the Stimulus Booklet that they are looking at within a specified time limit (Weschler, 2003). This test measures nonverbal concept formation and spatial organization and was used to estimate performance IQ.

**Children's Concussion Resolution Index (CRI-C).** The Children's Concussion Resolution Index (CRI-C; Headminder Inc., 2002) is a computerized neurocognitive test that assesses a child's functioning within the domains of reaction time, attention, concentration, working memory, and speeded decision making. The CRI-C is comprised of 11 subtests: Number Recall, Number Sequencing, Reaction Time, Cued Reaction Time, Animal Decoding, Visual Recognition 1, Symbol Scanning, Visual Recognition 2, Visuo-Motor Speed 1 (VMS1), Visuo-Motor Speed 2 (VMS2), and Visuo-Motor Speed 3 (VMS3). There are four indices derived from the subtests: Processing Speed (PS), Simple Reaction Time (SRT), Complex Reaction Time (CRT), and Attention/Working Memory (A/WM).

**Assessment of Soccer Heading Behavior.** Although self-report of soccer heading was obtained, on-field observation during the fall and spring competitive seasons provided the primary measure of heading. Parents completed the Soccer Head Impact Measurement Form for their own child during games. Measurement forms included the amount and type (direct or flick) of intentional headers that the child engaged in as well as the severity (mild, moderate, or severe). Parents also recorded the frequency and severity of unexpected ball-to-head impacts; head collisions with another player's head, arm, body, or foot; body-to-body collisions with another player; and head collision with the ground, goal post, or other fixed object.

## Procedure

Each parent and child provided background information through (a) a structured interview; (b) a questionnaire detailing their child's developmental, medical, and academic histories as well as soccer heading practices; and (c) completion of the Child Behavior Checklist (CBCL). While children were given the neurocognitive assessment, parents participated in a video-based training session on the observational techniques and documentation procedure for measuring the frequency and intensity of their child's heading during games. The duration of each session lasted between 1.5–2 hr. To examine the reliability of the soccer heading ratings by parents, the authors attended games intermittently and rated the frequency of soccer headings as well as conducted video analyses.

## Results

### Heading Measures

Observational soccer heading data were obtained for 27 players (19 girls and 8 boys) over multiple games. The average number of games that parents observed their child's soccer heading behavior was 6.68 with a range of 4–12 games. The

range of soccer headers per game was 0–3.8, with an average of 1.64 headers per game. Ninety-one percent (91%) of the children engaged in heading during the observational period. Of the 240 headers observed in all the children over the course of the season, 69.2% were direct headers (i.e., the ball was directed back in the same line, perpendicular to the forehead). The majority (58.2%) of the direct headers was categorized as mild; however, moderate (24.6%) and intense (17.2%) headers were observed. The remaining headers were flicks (i.e., the head was rotated to direct the ball at an angle from the original flight path). Although flicks were less common than direct headers (30.8%), mild and moderate intensity flick headers were distributed almost evenly (48.9% versus 44.4% of the time). Flicks of a severe nature were infrequent, being noted only 6% of the time. Interrater reliability estimates comparing the parents observations with those of the researchers exceeded 90%.

Self-report of heading relative to teammates and opponents correlated significantly with self-reports of heading frequency ( $r = .601, p < .001$ ) and with observed heading frequency ( $r = .430, p = .046$ ). Although observed heading and self-reports of heading correlated significantly overall ( $r = .508, p = .016$ ), the relationship was significant with the boys ( $r = .771, p = .015$ ) but not with the girls ( $r = .527, p = .064$ ). Since only 25% of the variance between self-report and observational data was accounted for, only analyses based upon the observational datum are reported. The smaller sample size reduces power and effect size but any differences or relationships obtained are more trustworthy.

In terms of other head impacts, no children experienced a head collision with another player's body during the observational period. Only four percent of the children experienced a head-to-head collision with another player. Of note, one child had a severe head collision with another player during the season. Nine percent of the children had either an unexpected ball impact to their head, and 9% had a head collision with another player's arm on at least one occasion. More than 45% of the children were observed to have had several body-to-body collisions (with no head impact), and most of these body-to-body collisions were categorized as moderate or severe.

**Age, Gender, and Soccer Heading Frequency.** Age correlated positively with heading frequency per game ( $r = .515, p = .05$ ). Soccer heading frequency by age is displayed in Figure 1. The 9-year-olds were never observed to head the ball, whereas those 13 and older headed at least twice per game on the average. Girls averaged 1.95 headers per game while boys averaged 1.18 headers per game; however, these averages were not significantly different ( $t = 1.559, p = .135$ ). The correlation of age with heading frequency was significant with the boys ( $r = .894, p = .001$ ) but not the girls ( $r = .057, p = .854$ ). Although preliminary, this suggests that girls exhibit heading activity at earlier ages than do boys.

**Height and Soccer Heading Frequency.** Children who were 5 feet 1 inch to 5 feet 8 inches tall averaged 1.95 headers per game, while children who were 5 feet tall and below averaged 1.37 headers per game. No significant differences or relationships were found between height and heading behavior.

**Player Position and Soccer Heading Frequency.** Figure 2 shows soccer heading by field position. Although midfielders appeared to head most often, the difference was not significant.

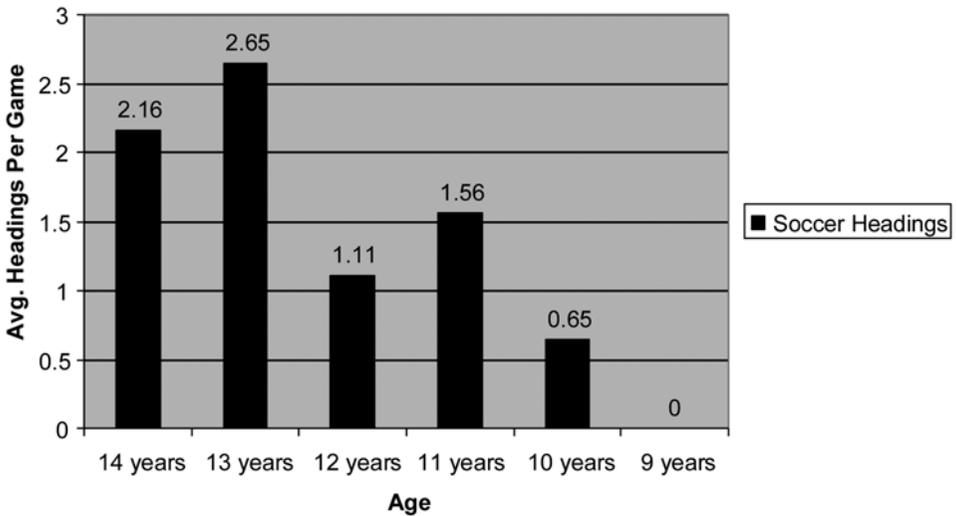


Figure 1 — Frequency of soccer heading as a function of age.

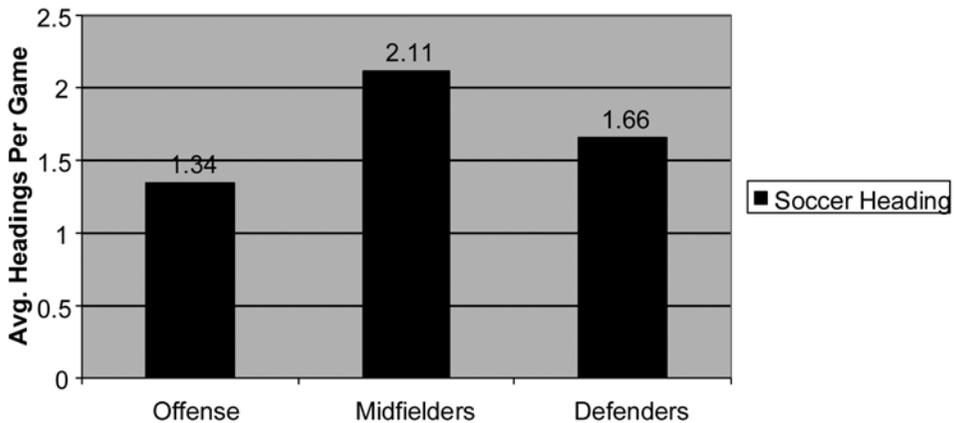


Figure 2 — Frequency of soccer heading as a function of playing position.

**Aggression/Headings Per Game.** Children’s self-report of their level of aggression relative to their peers was compared with the parental rating of aggression from the CBCL. Only 7 parents rated their child as aggressive. All 7 of those were among the 21 children who rated their own play as much more aggressive than peers. Nonetheless, no relationships were found between either measure of aggression and heading frequency.

**Soccer Heading Frequency and Neurocognitive Test Scores.** Soccer heading frequency was not related systematically to neurocognitive performance nor was there an interaction with ADHD status. Correlations were not significant for soccer heading frequency and the Trail Making Test, RAVLT, and Tower of

London measures. In addition, soccer heading frequency was not related to the Attention/Working Memory Index, Complex Reaction Time, and Simple Reaction Time Index on the CRI-C. Children who engaged in more soccer headings per game showed significantly lower Processing Speed Index scores. This indicates that they had slower response times on Animal Decoding and Symbol Scanning on the CRI-C. Children who headed the ball more frequently in games showed faster response times on Visuo-Motor 2 and Visuo-Motor 3 tasks with similar accuracy. Children who headed the ball more frequently in games also demonstrated fewer errors on the Visuo-Motor Speed 1 task.

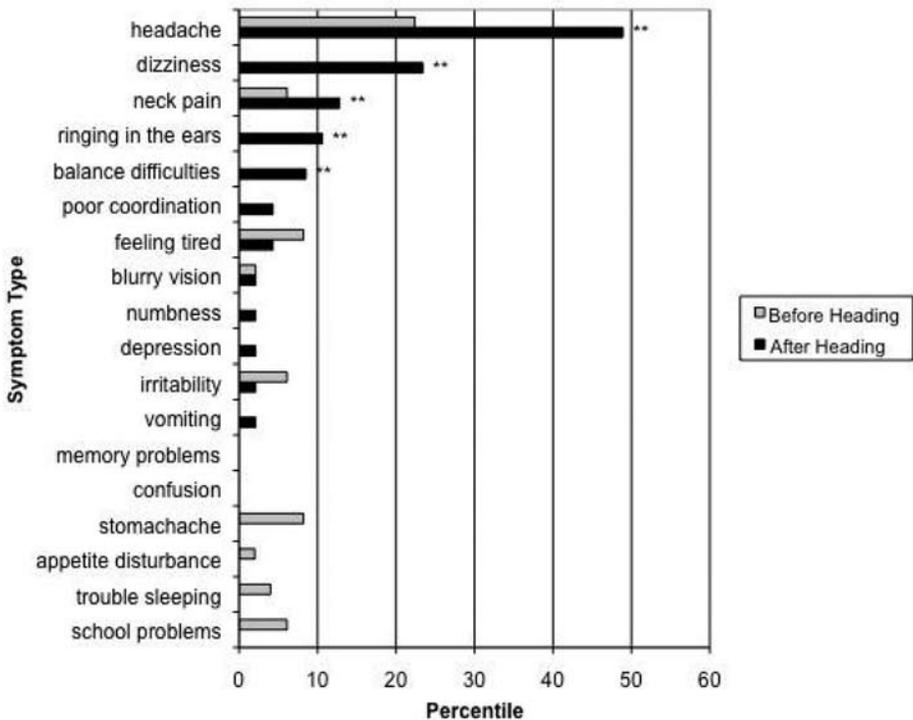
**ADHD Status.** Based upon existing or suggestive diagnoses computed from symptom profiles on the CBCL and parental interviews, 11 of the 49 participants were categorized as ADHD probable. In addition to the Attention Problems difference, significant differences were found for Anxiety/Depression ( $F = 10.650, p < .009$ ); Withdrawal/Depression ( $F = 12.844, p < .038$ ); Somatic Complaints ( $F = 96.239, p < .000$ ); Rule Breaking Behavior ( $F = 26.449, p < .000$ ); and Aggressive Behavior ( $F = 17.525, p < .000$ ). There was no significant difference found for Social Problems and Thought Problems.

On neurocognitive testing, significant differences were found between the ADHD categorized children and those not so categorized for ToLDX rule violations ( $F = 3.844, p < .05$ ); Block Design ( $F = 10.590, p < .01$ ); CRI-C Attention/Working Memory Index ( $F = 8.301, p < .01$ ); CRI-C Visuo-Motor Speed 1 errors ( $F = 5.425, p < .05$ ); and Visuo-Motor Speed 3 errors ( $F = 10.937, p < .01$ ). No significant differences were found in the multivariate or univariate comparisons for RAVLT, TMT, and WISC-IV Vocabulary.

Regarding soccer heading frequency, there was no significant difference found between ADHD and non-ADHD children. Both groups had a similar self-reported soccer heading frequency in games as well as actual headings per game.

**Symptom Reports.** Figure 3 shows symptom reports for current status and also following heading events. At baseline, headache, neck pain, stomach aches, and feeling tired were reported most frequently. All symptoms reported by children at interview were described as “not too bad.” Symptoms such as dizziness, poor coordination, numbness, memory problems, confusion, ringing in the ears, sleepiness, depression, poor balance, and vomiting were denied by all children at baseline. Age and gender were not significant factors in the report of current headache, stomachache, neck pain, or feeling tired. As shown in Figure 3, the outcomes of a series of Mann-Whitney  $U$  tests revealed that headache, dizziness, neck pain, ringing in the ears, and balance difficulties were reported significantly more following a heading bout than in the absence of heading ( $p < .01$ ).

Reflecting on their experience after heading the soccer ball, 48.9% of the sample reported headache while 23.4% reported dizziness. Children who reported headache following heading had a significantly higher observed and self-reported frequency of heading in games,  $t(20) = -2.370, p = .028$ , and  $t(45) = 2.519, p = .015$ , respectively. Older children (12–14 yrs) experienced headache after heading the ball at a significantly higher frequency than younger children (9–11 yrs),  $U = 166.50, p = .040$ ; however, there was no significant difference found for dizziness, ringing in the ears, or balance difficulties by age. The only gender difference for symptom report was found for balance where girls reported balance difficulties



**Figure 3** — Baseline and postheading reports of common symptoms.

more frequently than boys,  $U = 231, p = .05$ . Of the 23 children who reported headache after heading the soccer ball, 14.9% reported experiencing a headache for one hour or more. Overall, the duration of headaches reported ranged from a few seconds to 24 hr. Of the 11 children who reported dizziness after heading the soccer ball, 14.9% reported experiencing dizziness for more than a minute. Of note, one child reported balance difficulties for 20 minutes and another child reported ringing in the ears for more than one hour after heading the ball. All 49 children denied experiencing memory problems, confusion, stomach ache, appetite disturbance, sleepiness, sleep problems, or school problems after heading the ball. It was noteworthy that one of the participants who headed frequently and intensely reported multiple symptoms following heading including vomiting, which is suggestive of a concussive episode. No medical treatment was attempted.

## Discussion

Few studies have examined heading behavior in youth. The present study provides preliminary data on the epidemiology of soccer heading behavior in relation to gender, age, player position, height, ADHD, and aggression in children. Nearly all the children in the sample headed the ball at least once during the course of a

soccer season. The soccer heading frequency displayed by the sample in games was similar to that reported with high school and collegiate women (Kaminski, Wikstrom, Gutierrez, & Glutting, 2007) and less than reported with collegiate men (Rutherford & Fernie, 2005). In addition, the children in the sample more commonly engaged in direct headers in comparison with flicks, which may reflect the level of skill and strength of children this age. Although Rutherford, Stephens, and Potter (2003) summarize in their review that between 6–16 headers per player is observed in professional male players, little information is available concerning a breakdown of headers by intensity and type. The elaboration is not trivial since flick headers are likely to result in the rotational accelerations that many analysts have suggested may cause brain insults (Lees & Nolan, 1998). The participants also demonstrated a significant relationship between their self-reported frequencies of heading in games to their actual headings. However, the estimates were higher than the actual heading events in games, not dissimilar to what Rutherford and Fernie (2005) showed with adult players. Our findings show also that utilizing parents as raters of their children's soccer heading behavior can extend the reach of data collection outside of the laboratory and expand the amount of data collected. For example, the observations revealed that a large percentage of children experience body-to-body collisions of a moderate to severe nature. More investigations are needed to determine whether the impact of these collisions is strong enough to create acceleration-deceleration injuries in children.

We explored personal characteristics that may influence soccer heading frequency in children. Older boys headed the ball more frequently than did younger boys. This was consistent with our expectations and Webbe and Ochs (2007), who showed that older age correlates with increased heading behavior. Older children are stronger, have more experience playing soccer, and may have less fear of heading the ball, all of which may explain this phenomenon. Moreover, coaches appear to be more conservative in introducing heading with the younger children in the competitive teams that we studied. In our sample, girls and boys did not differ on soccer heading behavior, and girls showed heading behavior at an earlier age, which contradicts Janda et al. (2002) and Kaminski et al. (2007). Not finding a relationship between girls and age was surprising. While this may possibly be a function of a small sample size instead of an actual reality, this relationship will be further clarified as the study progresses. Regarding height, children who were tallest made greater estimates of their heading frequency relative to their teammates and opponents; however, no significant differences were found for actual heading in games. This contradicts Webbe and Ochs (2007), who found that height was the best predictor of heading for males aged 16–34. No significant differences for actual soccer heading behavior by player position were noted. We suspect that as the sample grows, differences will emerge given the trends in the current data where midfielders and defenders reported greater estimates for heading the ball in games in comparison with forward. That trend mirrors findings from previous studies (e.g., Webbe & Ochs, 2003). Future studies should explore type of headers as well as heading impacts by player position, as this may be important in determining risk injury potential for youth. It appears that aggressive behavior may not be a useful predictor of actual soccer heading in children of this age. This finding also suggests that children who are aggressive outside of the sports context are not necessarily aggressive within soccer as determined by soccer heading frequency.

ADHD children and children without ADHD showed a similar pattern of soccer heading frequency in games. Future studies should continue to explore the style of play of ADHD children in comparison with other youth athletes, given their propensity for engagement in risky activities and unique potential for injury.

Almost 88% of the children received formal heading instruction on their teams, including girls, which contradicts Janda and colleagues' (2002) explanation that girls are less commonly taught how to head the ball at young ages. Despite having familiarity with the proper technique, many children in the sample reported multiple symptoms postheading. Our study suggests that children may be likely to report physical symptoms after heading the ball. Given that many of the standard postconcussion symptoms are also among the most commonly reported symptoms generally (such as headache), it was notable to see the difference in self-report from current versus postheading instances, especially claims of symptoms such as dizziness, ringing in the ears, and balance problems that never were reported except following heading. The percentages of symptom reports such as headache were very similar to children's symptom reports by Janda et al. (2002). No concussions occurred in our sample during this period of data collection. However, the symptom reports were quite similar to those reported following concussion in adolescents and Olympic soccer athletes (Barnes et al., 1998). Most adult studies have not noted significant postheading symptom reports, commenting anecdotally that such reports are rare (Rutherford et al., 2003).

Parental ratings on the CBCL were evaluated to investigate whether ADHD children and non-ADHD children differed on internalizing and externalizing symptoms. Our findings show that ADHD children showed significantly more internalizing symptoms on the CBCL, such as anxiety, depression, and aggressive behavior than non-ADHD children. ADHD children in our sample also exhibited more somatic complaints than non-ADHD children without the presence of a head injury. Thus, it may be more difficult to interpret symptoms after heading the ball and/or concussion in this population. The 22% suggestive incidence of ADHD in this sample reveals the importance of ascertaining baseline performance in youth to make accurate assessments postinjury. We saw no indication that the premorbid factor of ADHD might interact with soccer heading in producing cognitive weaknesses. On the other hand, significant differences were found between ADHD groups and non-ADHD children on baseline testing (ADHD children exhibited significantly more ToLDX rule violations, significantly lower Block Design scores, as well as more errors on the nonverbal CRI-C Visual Motor Speed 1 and 3 tasks). These warrant some consideration and should continue to be explored in future studies of youth soccer heading behavior and neuropsychological functioning.

When studying soccer heading, Rutherford and Fernie (2005) recommended that observational data and identical methods to gather heading frequency should be used. They also suggested separating players from different levels of competition. In terms of broad methodological issues, Satz and colleagues (1997) outlined six criteria that comprise an adequate research design in this field: (a) a longitudinal design with follow-up greater than 12 months, (b) inclusion of an appropriate control group, (c) a clear definition of mild HI, (d) a control for preinjury factors, (e) a sample size of > 20, and (f) use of standardized assessment measures. The current study was designed with these criteria in mind.

## Recommendations

Based on our review and findings, we make several recommendations to maintain safety in youth soccer: (a) young children who are less than 12 years old should avoid heading the ball in games since their body mass and neck musculature have not yet developed; (b) given a propensity for heading behavior in young children, they should be instructed on the proper heading technique to increase competency in this skill and reduce injury; instruction should include suggestions on how to properly flex neck muscles and how to prepare for a direct header versus flick to prevent injury; (c) flicks may be taught to children once they have shown competence in basic direct headers given the greater skill required; the authors recommend that young children should not engage frequently in flicks of a moderate to severe nature given their weak neck musculature; (d) children should be monitored for correct heading technique in games given the likelihood that these headers will be more intense than at practice; (e) because many children may report symptoms after heading the ball, it is important to educate coaches and parents about concussion-like symptoms to make an early identification of injury; (f) although children with ADHD may have developed premorbid compensation strategies, it is important to explain emotional reactivity and other symptoms that may arise from heading the ball or other injury sources; (g) coaches and parents should emphasize the importance of safe play and should err on the side of caution concerning a player's reentry into game play after symptom reports or an injury; children should not return-to-play if they report concussion-like symptoms after heading the ball and/or any head impact; (h) neurocognitive measures along with questionnaires would be useful in going beyond a child's self-report of symptoms during a game so that return-to-play decisions are accurate; (i) funding or resources should be made available to soccer organizations so that qualified trainers can monitor youth games in the event that concussions take place; and (j) baseline testing and postinjury assessments should be valuable to youth soccer programs in helping to identify concussion in youth athletes as well as dispelling the ambiguity surrounding heading behavior and potential cumulative effects.

## Limitations

Due to logistical reasons, we were not able to obtain soccer heading frequency in multiple games for all of our participants. Further, there is not a proportional representation of age groups. This can make it difficult to understand the role of heading behavior and cognitive correlates in the context of age, gender, ADHD status, and other personal characteristics. Future studies should aim to have matched cohorts that control for these factors. Due to the limitation of children who engaged in intense heading and/or who had a history of concussion, only soccer heading frequency was evaluated. Our soccer heading data were based on parent reports. Although our study suggests that they are reliable reporters, future studies should use more frequent intermittent reliability checks of soccer heading behavior in games. Although repeated follow-up assessments are planned for future research, there was limited availability for this opportunity in this initial study. Finally, postheading symptom reports were obtained retrospectively rather than immediately following the events.

## Conclusion

The data presented herein represent the first year of a five-year study. One positive finding is that overall, analysis of our first-year outcomes suggests that children, especially young ones, do not engage in soccer heading as frequently as the adolescent and adult population. An additional positive finding is that in contrast to some studies with adolescents and adults, no neurocognitive evidence was uncovered to suggest that the observed level of child soccer heading posed significant risk. Of concern, however, were the retrospective postheading symptom reports of the children. These were similar in pattern and percentage to those seen in adult players following concussive brain injuries, and were considerably greater than retrospective postheading reports from older players. Continued study of this active cohort and children newly recruited into this study should clarify acute and cumulative risk of soccer heading among children.

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