5-1998

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A Thesis Submitted to the Graduate Faculty
Of the University of Richmond
In Candidacy for the Degree of
MASTER OF ARTS in Psychology

May, 1998
Richmond, Virginia

Acknowledgement

I gratefully acknowledge the faculty in the Department of Psychology at the University of Richmond for their enthusiasm, support, and encouragement. I would like to thank Dr. Jim Tromater, Dr. Craig Kinsley, and especially Dr. Barbara Sholley for their expert advice and assistance in completing this research project. I would also like to thank Erin and my family for their patience and understanding.

I certify that I have read this thesis and find that, in scope and quality, it satisfies the requirements for the Master of Arts Degree.

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Neuropsychological Performance and Player Characteristics In Amateur Soccer Players

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Abstract

A growing body of research suggests that the game of soccer causes neurophysiological damage and neuropsychological deficits in its players. This research project evaluated player characteristics, including aggression, position, heading frequency, and head injuries in an attempt to delineate the effect of traumatic head injuries from the possible detrimental effects of heading the ball. Fifty-three male, amateur soccer players participated in a brief neuropsychological evaluation and a structured interview. Findings revealed that the number of years played ($r = .30$, $p = .03$) and an index score representing the number of competitive seasons ($r = .44$, $p = 001$) were the only player characteristics that correlated with test performance. Results also suggest that past research has underestimated the connection between heading frequency and aggression ($r > .4$, $p \leq .002$), a variable that may be related to head injury.

Neuropsychological Performance and Player Characteristics in Amateur Soccer Players

Soccer is the most popular sport in the world. With the World Cup held in the United States in 1994, the reinstatement of a legitimate professional league, and the rapid growth in popularity among our nation's youth, soccer is fast becoming one of this country's most popular sports. While some researchers suggest that soccer is a relatively safe sport, a growing body of research (Spear, 1995; Autti et al, 1997; Dailey, 1992) provides evidence that people who play soccer are at risk for neurophysiological damage and neuropsychological deficits similar to those associated with minor head injury.

Though physically tame in comparison to boxing, football, and hockey, soccer is most certainly a contact sport. Aggressive play wins games and collisions between players, both accidental and deliberate, are often within the rules of the game. Head injuries can occur through contact with other players, the ground, or the goal post. However, the purposeful use of the head in directing the ball is unique to soccer. Recent research and resultant media coverage have caused widespread concern that repeated heading of the soccer ball may cause chronic brain injury (Tysvaer, 1992; Witol, 1993; Goleman, 1995). While sound in their basic logic, these studies are methodologically flawed and extremely limited in their findings. Results from more comprehensive and advanced studies suggest that the neurological differences and neuropsychological deficits found in soccer players are due primarily to incidental body contact and acute head injuries (Barnes, McDermott, Cooper, & Garret, 1994; Jordan et al, 1996).

Head injuries are generally divided into five categories: extracranial injuries, skull fractures, penetrating injuries, focal brain injuries, and diffuse brain injuries (Gennarelli, 1993). For the purpose of our review, we will focus on the types of head injury that are most pertinent to the current study. Focal brain injuries include contusions, lacerations, and hemorrhage and hematoma that occur within the brain. Diffuse brain injuries include brief coma, unconsciousness, concussion, and prolonged posttraumatic coma. Minor brain injury is generally defined as an immediate and transient impairment of neural function and is likely to occur in soccer players as a result of dynamic loading to the brain transferred by either a direct blow to the head (impact) or sudden movement of the head (impulse) due to forces applied elsewhere on the body (Wilberger, 1993).

Both impact and impulse loading to the head can result in compressive, tensile, and shearing forces applied to the brain. Compressive forces occur at the point of contact, while tensile forces are opposite of compressive and often referred to as negative pressure. Shearing force is applied parallel to the brain's surface and is particularly damaging to neural tissue. A forceful blow to the resting, movable head is likely to produce compressive force and injury beneath the point of cranial impact and is called coup injury. However, when the head is moving, the brain lags towards the trailing surface of the skull. When the protective cerebrospinal fluid is displaced and the distance between the brain and the irregular inner-surface of the skull is reduced, contra-coup injury is likely to occur opposite the point of impact. It is important to note that an athlete who is prepared for contact is less likely to sustain head injury (Cantu, 1992). A derivative of Newton's law states that force divided by mass equals acceleration. The head of a player who is unprepared for contact will have a mass that is equal only to the weight of the head, while a player who is prepared and has tensed their neck will add much of the body's mass to the equation and reduce the acceleration forces on the head.

The biomechanical variables that affect traumatic head collisions on the soccer field are complex and likely to be unique in each case of injury. In the simplest of injury scenarios, the direction, speed, and mass of the player's head interact with the direction, speed, and mass of the impact or impulse exerted to create loading forces on the brain.

While some impacts to the head are simple head to head contact, many injuries are likely to involve multiple collisions producing a myriad of loading forces. As stated earlier, these forces can have the mass of a metal post and the speed of a head on collision. At the heart of the current debate is whether or not the purposeful and repetitive heading of the soccer ball provides sufficient loading force to produce cumulative brain trauma in soccer players.

Research by Tysvaer and colleagues forms the basis of the physiological literature suggesting that heading the soccer ball causes brain damage. Tysvaer & Storli (1989) performed neurologic and electroencephalographic examinations (EEG) of 69 active professional soccer players and a control group of 69 men matched according to age. They also recorded EEG-telemetry in four soccer players during and after a ten minute session of intense heading. The soccer group was split into *header* and *not-header* groups on the basis of self-assessment and the opinion of managers, teammates, and supporters. In all but one player, neurologic examinations proved normal. Although players with more protracted and permanent complaints had a higher percentage of abnormal EEGs, the difference was not statistically significant and all abnormal EEGs were obtained from the *not-header* group. Chi square analysis revealed a significant difference in the number of normal EEGs between the soccer players (65%) and controls (87%). All four players examined after intense heading for about 10 minutes experienced headaches, but only a small increase in the amplitude of resting alpha rhythm that lasted, on average, 1.8 seconds.

The EEG difference between players and controls should not be regarded as surprising considering more than half of the soccer players (54%) had suffered game related head trauma, whereas the control group was screened and found to be free of head and neck injuries. In their explanation of why *non-headers* and younger players had a higher incidence of abnormal EEGs, the authors postulated inexperienced or incorrect heading technique. However, this explanation seems to be undermined by the findings of

Ross, Cole, & Thompson (1983) who found that EEG abnormalities in boxers were significantly correlated with the number of bouts fought. Thus, as fighters became more experienced, they incurred more abnormal EEGs. Tysvaer abandoned the *incorrect heading* theory in later research as his results were inconsistent with those found in this study. In their assessment of the EEG measures during and after heading sessions, Tysvaer & Storli regarded the EEG outcomes as "only slight temporary changes" (p. 577).

Tysvaer, Storli, & Bachen (1989) conducted a neurological and EEG examination of 37 former soccer players of the Norwegian national team and compared them to controls that were chosen arbitrarily from different occupational groups. The soccer group was split into *header* (10) and *not header* (27) groups on the basis of self-assessment, newspaper reports, teammates, and knowledgeable observers. The neurological examination included assessment for nystagmus, impaired coordination, reflex disturbance, impaired hearing, unsteadiness, and reduced motion of the cervical spine. Twenty-six players, including all 10 *headers*, demonstrated neurological deficits. Reduced movement of the cervical spine was found in all *headers* and in 12 of the *not headers*. The control group revealed no signs of neurological deficits. While there was a difference in the number of players (25) and controls (33) who had normal EEGs, there were no EEG differences between the *header* and *non-header* groups.

Again, the neurologic and EEG differences between the soccer and control group are to be anticipated. The players averaged over 350 games at the professional level and 70% had experienced acute head trauma during the course of their careers, whereas the controls were screened and found to be free of any head and neck injuries. Though *headers* appeared to be more susceptible to reduced motion of the cervical spine, there was no evidence suggesting that *headers* were more prone to abnormal EEGs.

Sortland & Tysvaer (1989) examined 33 former soccer players, aged 39-68 years, from the National Team of Norway using cerebral computed tomography (CT). Nine of the former players considered themselves to be *headers* and "were also regarded as such by others" (p. 44). CT measurements were compared to a 1977 sample of 26 Danish males aged 41-72 years. Results demonstrated cerebral atrophy with widening of the lateral ventricles in one third of the soccer players. *Headers* were found to have significantly higher frequency of cortical atrophy.

Although Sortland & Tysvaer admitted that the control group was less than ideal, they made only brief reference to the fact that seven of the 33 players had suffered one or more soccer-related head injuries that resulted in unconsciousness or amnesia. Most importantly, the difference in cortical atrophy between the *header* and *non-header* groups was confounded by the statistically significant higher age of the *header* group. Research by Barron, Jacobs, and Kinkel (1976) suggests that older people are more likely to demonstrate the cortical atrophy that the researchers found in their older *header* group. While noting the flaws in their study, Sortland and Tysvaer still concluded "that the atrophy probably was caused by repeated small head injuries mainly in connection with heading the ball " (p. 44).

While Tysvaer's physiological studies raise serious concerns as to the long-term effects of professional soccer, they do not scientifically establish heading the soccer ball as a mechanism of injury. Their assessment of heading frequency and subsequent placement of players into *header* or *not header* groups was extremely vague and impossible to replicate. Tysvaer's studies also lacked adequate control groups. Even using samples that were more representative of the general population would have strengthened Tysvaer's conclusions. However, in two of the three studies, the control group was screened for head and neck injuries. Tysvaer and his colleagues also overlooked alternative sources for brain injury in assessing their results. They reported the incidence of head trauma in their soccer groups, but did not provide any data on the possible relationship between heading frequency, soccer related brain injuries, and neurological deficits.

Four neuropsychological studies have been conducted suggesting that soccer may cause brain damage similar to that found in patients who have sustained minor head injuries. However, these efforts are plagued with methodological flaws similar to those found in Tysvaer's physiological research. Abreau, Templer, Schuyler, & Hutchison (1990) conducted a neuropsychological assessment of 31 soccer players and 31 tennis players, both recruited from local colleges. The soccer players had a significantly greater number of complaints, including blurred vision, dizziness, and loss of consciousness following a game. A multiple analysis of variance did not reveal significant differentiation between the two groups on the measures of attention and concentration. However, for soccer players, there was a significant negative correlation between performance on the Paced Audio Serial Addition Test and the number of games played (-.41).

Unlike Tysvaer and his colleagues, Abreau et al. (1990) took great care in qualifying their results. They noted that the number of headings was not negatively or significantly correlated to any of the neuropsychological measures. Most importantly, they acknowledged that it is not possible through their research design (identical to that of Tysvaer's) to "isolate the effects of heading the soccer ball from the effects associated with the other sort of head contact in the game of soccer" (p. 179).

Murelius & Haglund (1991) conducted a neuropsychological assessment of Swedish amateur boxers, professional soccer players, and track and field athletes. Though the primary focus of their study was boxing, the authors specifically chose a soccer control group because they assumed that they "face the risk of brain injury due to heading" (p. 12). While they found no significant differences in impairment between the three groups, they did find that the length of careers for both boxers and soccer players correlated with poor performance on a motor test. While this kind of impaired motor performance has been associated with damage to the cortex in the frontal lobe, their research design made no effort to determine the mechanism of injury.

Tysvaer & Løchen (1991) examined 37 former soccer players of the National Football Team of Norway and a control group matched on age and education. Test results were consolidated into key scores for quantitative analysis. The soccer group was split into headers (10) and non-headers (27) on the basis of self-assessment, newspaper reports, teammates, and knowledgeable observers. The authors found a larger difference between verbal IQ and performance IQ in the soccer players, impaired visuomotor tracking scores for the players, and substantially more players in the impaired range on consolidated key scores. There was also a higher degree of severe to gross neuropsychological impairment in headers (20%) than non-headers (8%), though this difference was not statistically significant.

The control group of 20 hospitalized patients was screened for brain damage through neurologic and EEG examinations and considered free of brain injury, whereas 70% of the players had experienced soccer related head trauma. Though the authors emphasized the discrepancy between verbal and performance IQs in soccer players, this difference appears to be the result of the players' atypically high scores on the information, comprehension, and arithmetic portions of the verbal section. Finally, the authors utilized a statistically non-significant difference in neuropsychological key scores to reach the unsupported conclusion "that blows to the head by heading show convincing evidence of brain damage similar to that found in patients who have sustained minor head injuries" (p. 59).

Witol (1993) investigated the presence of neuropsychological deficits associated with heading and experience in playing soccer. She examined 60 soccer players, divided them into 3 age groups (15 to 17; 19 to 22; and 25+) and 3 heading groups (low, medium, and high), and compared them with 12 controls. Results suggested that players with more playing experience and higher heading frequency performed at a lower level on some tests of searching, attention, and mental flexibility. She concluded that the "study's findings indicate that soccer play is not harmless; certain variables associated with soccer play, including experience and heading frequency cause changes, and at times deficits, in the athlete's cognitive functioning" (p. 97).

Witol's research represents the first neuropsychological study to reveal statistically significant test performances differentiated by heading frequency. In doing so, this study has provided some of the strongest evidence to date that heading is related to neuropsychological deficits in soccer players. Perhaps Witol's most significant improvement on past research is a more detailed measurement of heading frequency that allowed her to create 3 groups based on per game estimates of heading. However, Witol overstepped the boundaries of her quasi-experimental study with her attribution of causality. Her study, like those before it, neglected to analyze head traumas due to the physical contact that is inherent to the sport of soccer.

More recent studies suggest that the occurrence of traumatic head injuries in soccer has been underestimated or overlooked by past research. Barnes, McDermott, Cooper, and Garret (1994) conducted a written survey of 72 American males participating in the 1993 U.S. Olympic Festival. Demographic factors were recorded as well as each player's estimation of heading frequency, comparison to other players' heading, and reported symptoms after heading. Head injuries and the circumstances surrounding the injuries were also recorded. Only those injuries severe enough to warrant hospitalization, medical or dental attention, removal from a game or practice, subsequent evaluation, or sequela were reported. Eighty-nine percent of the players experienced some type of head injury during their soccer careers, with a total 65 concussions in 36 players. Though the authors could not rule out the combined effect of concussive injuries and heading the soccer ball, their findings demonstrate an alarming rate of head injury and highlight the need to determine how it may interact with heading.

Becchi, Merli, & Corradini (1993) examined surveys administered to 2,455 head injuries admitted from 1986 to 1991 to the Neurosurgical Division in Modena, Italy. Their analysis revealed that soccer was the sport most commonly linked with head trauma (35.7%), far surpassing horse riding (12.2%), downhill skiing (12.2%) and cycling (9.2%). While the popularity of soccer in Italy is certain to affect the epidemiology of injuries, the findings of Becchi et al. further emphasize the risk of acute head injury that is inherent to the game of soccer.

In the most medically advanced study to date, Jordan et al. (1996) assessed 20 active, male, elite soccer players with a head injury symptom questionnaire and magnetic resonance imaging (MRI) and compared them to 20 age-matched, male, elite track athletes. Information collected from soccer players included position, team, number of headers, acute head injuries, and years of playing experience. The results revealed no statistical differences between the soccer players and track athletes with respect to symptom or MRI measures. Within the soccer group, there was no correlation between MRI results and age, years of play, heading exposure, or number of headers. However, soccer players' head injury symptoms were correlated with a history of prior concussion ($r=0.63$), suggesting that neurological impairment in soccer players is primarily related to acute head injury. Green et al. concluded that "neither the MRI data nor symptom results suggests any evidence for the existence of a chronic brain syndrome secondary to cumulative trauma related to heading soccer balls" (p. 1).

The current research endeavor is based on the hypothesis that the neuropsychological deficits and neurophysiological differences demonstrated in past research are due primarily to head injuries that are the result of contact with the ground, goal post, and other players. It is likely that Witol and Tysvaer, with their respective measurements of heading frequency, inadvertently tapped into an aggression index for soccer players. In other words, the more aggressive the player, the higher the frequency of heading. Logically, it follows that more aggressive players would be more likely to initiate the type of physical contact that can result in head injuries. If this is the case, and heading frequency serves as an indicator of aggression instead of a tabulation of sub-concussive blows, then heading frequency may correlate with, but not cause neuropsychological deficits.

This pattern may be further compounded by the central positions and key roles that more aggressive players are likely to assume on the field. Because tenacity and the ability to win the ball in the air elevate performance, coaches are likely to appoint the more aggressive player to the most critical positions in the center of the field. Under this positional theory, players who are both more aggressive and located in high traffic areas of the field are more likely than their teammates to initiate the type of contact that may result in head trauma. Limited support for this positional theory is provided by Hunt & Fulford's (1990) analysis of 200 amateur soccer players attending the accident and emergency department at King's College Hospital in London. In their investigation of field position and its relation to injury frequency, they found that the center half accounted for the most injuries with 35.5% of all the injuries presented. While there was no record kept for central defenders, the center forward was second with 16.5% of injuries. Though the two positions take up only 18.2% of a team's starting eleven, they accounted for 52% of the injuries in the Hunt & Fulford study. While sprains, fractures, bruises, and lacerations accounted for the majority of injuries suffered across all positions, all head injuries occurred in either the center half or center forward positions. Similarly, Latella, Serni, Aglietti, Zaccherotti, and DeBiase (1992), in a survey of injuries in 1,018 members of an Italian soccer league, found that center forwards were most likely to suffer injury.

In an attempt to view the possible mechanisms of head injury in soccer players within a more comprehensive framework, the current study examines the positional theory explicated earlier and heading frequency as a possible indicator of aggression while measuring player characteristics previously ignored in the literature. It was hypothesized that *heading frequency*, *aggressive play*, *field position*, and *soccer related head injuries* would be related to each other and to neuropsychological outcome. It was postulated that *heading frequency* would correlate with neuropsychological scores, but that once the shared variance from *soccer related head injuries*, *aggression*, *playing experience* and *field position* were covaried out, *heading frequency* would have a minimal association with neuropsychological outcomes. After a thorough review of the literature, it was decided that comparing soccer players to an inappropriate control group would only place unnecessary limitations on the interpretation of results. This study was designed to compare players of varying levels to each other in an attempt to clarify how aggressive play, field position, head injuries, and heading frequency relate to neuropsychological performance in amateur soccer players.

Method

Participants

Neuropsychological data and interview information was collected for 60 male amateur soccer players. All subjects were recruited from Richmond, VA and Little Rock, AR. The 53 players who comprised the sample ranged in age from 19 to 33 with a mean of 26.4 years and a standard deviation of 3.79. Their years of education ranged from 13 to 18 with a mean of 15.84 and a standard deviation of 1.02. The average number of years the sample had played soccer was 19 with a standard deviation of 4.37.

Instruments and Rationale

All subjects were volunteers playing men's amateur soccer at the time of the evaluation. Players were recruited through personal contacts or from the playing field and evaluated in quiet and isolated environments. Testing generally took place in the home of the subject or experimenter, but was conducted at subjects' offices on several occasions. The nature of the study was explained and each subject was allowed to read and sign the consent form. Measures were administered in the following order: PASAT, Trails A & B, Pegboard, Block Design, and structured interview.

Selection of specific neuropsychological tests was based primarily on the results of previous investigations with soccer players. More global neuropsychological and intelligence assessments were avoided in an attempt to keep the battery time-efficient and domain specific.

The **Trails Making Test** (TMT) is a two part test (A & B) of visual conceptual and visuomotor tracking with a motor speed component. Tysvaer & Løchen (1991) found that controls performed significantly better than soccer players on both sections of the TMT, but did not present data in relation to *headers* versus *non-headers*. Witol (1993) found that players with higher heading frequencies took significantly more time to complete TMT-A & B. TMT-A requires the subject to draw lines connecting consecutively numbered circles on a work sheet. TMT-B, using a similar format, requires alternation between consecutive letters and numbers and includes a mental flexibility component. Subjects were asked to connect the circles as fast as possible without lifting the pencil from the paper.

Utilizing the Reitan method of scoring, subjects were alerted to errors during the trials and the total time to completion served as the final score.

This scoring method is most common and penalizes for errors indirectly by causing the subject to take more time to completion. While the Reitan method does not control for differences in response times and correction styles that can result in variability across examiners, there was a single examiner in this study. Though education and age affect performance on the TMT (Lezak, 1995), the subjects participating in this study were fairly homogeneous in these areas. While reliability coefficients for the TMT vary considerably due to wide-spread use of the test with diverse populations, most estimates are above .60 with many in the .90s (Lezak, 1995). Performances by patients with mild head trauma are slower than those of control subjects, and slowing increases with severity of damage (Leininger et al., 1988). The TMT has also contributed significantly to the prediction of independence achieved for a group of moderately to severely injured head trauma patients (Acker and Davis, 1989). The TMT is time-efficient, has been used often in the study of soccer players, and appears reliable and valid in its measurement of mild head trauma.

The **Grooved Peg Board** (GPB) was selected to measure complex motor coordination. Witol (1993) and Abreau (1990) opted not to utilize a motor test and Tysvaer & Løchen (1991) neglected to report any data on their GPB assessments. However, Murelius & Haglund (1991) found a significant correlation between the length of soccer career and inferior finger-tapping test results in both the dominant and non-dominant hand. Though motor tests abound in the field of neuropsychology, most were designed to assess the gross motor deficits found in more profoundly impaired patients. The GPB was chosen for its complexity of task and the ease with which it can be administered. The test consists of a small board containing a 5 X 5 set of slotted holes and 25 metal pegs with ridges that must be rotated into the correct position before insertion. The dominant hand was assessed and the score is the time to completion. Little data exist on the reliability and validity of the GPB. However, Lezak (1995) suggests that its complexity makes it a sensitive measure of motor deficits.

The **Paced Auditory Serial Addition Test** (PASAT) (Gronwall, 1977) is a demanding test that is sensitive to deficits in attention and information processing that are commonly associated with minor head injury. While Witol's (1993) use of the PASAT did not reveal any discernible trend between groups, Abreau et al. (1990) found a significant negative correlation between performance on the PASAT and the number of soccer games played (-.41). The test requires that the subject add 100 pairs of digits so that each is added to the digit immediately preceding it. For example, if the numbers given are "3, 8, 3, 5, 4", the correct responses (starting after the subject hears the second digit) would be "11, 11, 8, 9." The numbers are presented at four rates of speed, each differing by 0.4 sec and ranging from one every 1.2 sec to every 2.4 sec. To maintain control of such precise rates, the numbers are presented by tape recorder. Performance is evaluated by percentage correct.

The PASAT is a speed based test, so it is not surprising that age and education effects have been reported (Lezak, 1995). It was assumed that the homogeneity of the group would avoid such problems. However, there appeared to be a non-significant trend ($r = -.23$) for younger players to perform better on the PASAT. The PASAT has successfully differentiated between postconcussion patients and control groups (Gronwall & Sampson, 1974) and has a reported a split-half reliability of .96 (Gronwall, 1977).

The **Block Design** (BD) subtest from Wechsler's (1981) WAIS-R measures visuospatial conceptualization, visuoconstruction, problem-solving, manual dexterity, and speed of mental processing. Tysvaer & Løchen (1991) utilized the WAIS (with BD as a subtest) and Murelius & Haglund (1991) used the BD in their neuropsychological batteries.

While neither report BD differences between their groups, all researchers in this area have utilized some measure of higher mental functioning in their neuropsychological battery. Also, neither study utilized head injury as a variable or heading frequency in an interval fashion. The BD is a construction test in which the subject is presented with four or nine red and white blocks (depending on the item) with two white sides, two red sides, and two half-red/half-white sides divided along the diagonal. The task is to construct 9 replicas of block designs. Test scores depend on the number of designs completed within the allotted time and speed bonuses.

The WAIS-R manual provides split-half reliability coefficients for block design that run from .83 to .89 (Wechsler, 1981). Snow, Tierney, & Zorzitto's (1989) assessment of test-retest reliability at one year with a well-educated group of older adults was high (r=.84). Lezak (1995) asserts that "Block Design scores tend to be lower in the presence of any kind of brain injury" (p. 592). However, BD deficits are most likely to be more pronounced when the lesions involve the posterior and parietal areas of the right side of the brain (Reitan, 1986). The BD is often considered a crude, but efficient measure of intellect as it has loaded heavily onto a *complex intelligence* factor (Baser & Ruff, 1987) and correlates highly with general mental ability (Benton, 1984).

Structured Interview data for each subject included information on: age, education, total years played, how many years of competitive soccer, number of seasons played in last 5 years, alcohol and drug use, number and severity of head injuries off the field (symptoms and circumstances), number and severity of soccer related head injuries (symptoms and circumstances), heading skill, frequency of heading, whether or not they consider themselves to be headers or non-headers, all-around skill, athletic ability, aggression, all-around play, and position on the field.

The information regarding the number of years and level of competition was transformed into a weighted index. Using a formula similar to Jordan et al.'s (1996), players were given 1 point for each year played in high school, .5 for each year they played college club or intramural, and 2 points for each year played in NCAA. The rationale behind this kind of weighted system makes an important distinction in the frequency and intensity of both practice time and the physical nature of the game at various levels. The obvious difference between the weighted system in this study and Jordan's is the experience level of the players. While his research examined elite players with international, professional experience, this study focuses on amateur players and had only one player with limited professional experience.

Head injuries, suffered both on and off the field, were graded using the Colorado Medical Society's (1991) guidelines for the management of concussion is sports. These guidelines, which were designed for widespread use by trainers and coaches, utilize specific and readily determined symptoms to assess the severity of head injury. Confusion without amnesia and no loss of consciousness warrants a score of 1. Confusion with amnesia and no loss of consciousness warrants a score of 2. Any loss of consciousness is considered a grade 3 concussion. Each subject's head injury history was rated by both the experimenter and a neuropsychologist who was blinded to subject test performance and demographics. The straightforward guidelines were a benefit to subjects trying to recall symptoms from past injuries and produced perfect inter-rater reliability in head injury scores. The scores for the soccer head injury and overall head injury measures are the sum of the injury scores incurred by each subject. It should be noted that soccer head injuries were included in the overall score.

Heading frequency per game was estimated by each subject. Utilizing calculations similar to Witol's (1993) method of indexing, per game estimates were then multiplied by the weighted playing index to achieve a heading index. Witol attained a similar measure for her subjects by multiplying per-game heading estimates by the number of years played. This study opted to use the weighted index, introduced by Jordan et al. (1996), as the multiplier because it is likely to be a more detailed measure of playing experience, duration, and intensity. Jordan et al. suggested that this computation resulted in an exposure index that could be used in a dose-response research paradigm. Both the *per game* and *index* measures were examined in the final analyses.

Measures of heading skill, all-around skill, athletic ability, aggression, and all-around play were obtained through the combination of self-assessment on a one to ten scale and an additional point when a subject considered themselves to be one of the top three on their team in that area. This approach was chosen in the hopes that it would provide a more thorough self-evaluation and additional variability in scores.

Results

Four players with goalkeeping experience and one who played semi-pro, American football were omitted from statistical analyses. Two other players were excluded who have suffered serious head injuries and no longer head the ball due to doctors' orders. These seven subjects were eliminated from the data because the absence of heading, higher incidence of severe head injuries, and altered style of play made them incompatible with the rest of the group.

The 53 players that comprised the sample had an average soccer head injury score of 1.43 with a standard deviation of 2.47 and a range of 0 to 11. Twenty-three subjects (43%) reported that they had suffered at least one grade one concussion on the soccer field. The overall head injury score, which includes soccer related head injuries, averaged 2.96 with a standard deviation of 3.16 and a range of 0 to 12. Fourteen of the players (26%) reported no head injuries either on or off the field.

The average estimate of heading frequency was 5.72 times per game with a standard deviation of 4.69. Heading estimates varied widely between subjects. They ranged as low as one per game to as high as twenty-three and this skewed distribution was magnified in the calculation of the heading index, which averaged 42.4 with a standard deviation of 48.14 and a range of 2 to 240. The weighted index, used as the multiplier in the heading index, averaged 6.92 with a standard deviation of 3.46 and a range of 1 to 18. Aggression estimates averaged 8.28 with a standard deviation of 2 and ranged from 4 to 11.

All data were analyzed by SPSS 6.1 for Macintosh. Two-tailed Pearson's correlations between the neuropsychological measures of GPB, PASAT, TMT-A, TMT-B, and BD are presented in Table 1. GPB, a measure of fine motor skills and manual dexterity, did not correlate substantially with the PASAT, TMT-A, or TMT-B, but correlated significantly with BD, the only other measure containing a fine motor skills component. Because GPB did not correlate with any of the player characteristics included in this study and did not lend itself to a factor analysis of neuropsychological performance, it was dropped from data analysis. The remaining neuropsychological variables of PASAT, TMT-A, TMT-B, and BD correlated in the expected directions, with relative strength, and statistical significance.

PASAT scores averaged 91.25 with standard deviation of 6.95. Performance on TMT -A and B averaged 21.09 and 47.67 seconds with respective standard deviations of 5.58 and 11.49 seconds. BD scores averaged 41.06 with a standard deviation of 7.43. Performance on these measures was factor analyzed to create a single neuropsychological performance variable (NEURO). Kaiser-Meyer-Olkin's measure of sampling adequacy (.69) revealed that partial correlations were high enough to warrant factor analysis. Principle components extraction revealed a single factor with an eigen value of 2 that accounted for 49.9% of the variance, so that no rotation techniques were necessary. The strength, direction, and communality of each measure's relation to the NEURO factor is presented in Table 2. It is important to note that the time based measures loaded positively while the score based measures loaded negatively. In other words, better performance times in the TMT-A and B and higher scores on the PASAT and BD resulted in lower NEURO scores.

Factor analysis was utilized so that a regression analysis could be performed without inflating the probability of error. A standard multiple regression was performed with the NEURO factor as the dependent variable and aggression, position, soccer head injuries, and heading index scores as independent variables. None of the IVs contributed significantly to the prediction of NEURO performance (F (4,48) = 1.51, p = .21). The results of the regression indicated a statistically non-significant R of .33 with R squared accounting for only 11% of the variability in NEURO scores. While the regression analysis provided little information on how aggression, position, soccer head injuries, and heading frequency relate to neuropsychological functioning, the factor analysis was beneficial because it condensed the neuropsychological measures into one meaningful variable. The factor score derived for each participant proved useful in analyzing and presenting the remaining data in a more succinct and effective way.

The hypothesis that heading exposure, aggressiveness, field position, and soccer related head injuries would be both correlated to each other and neuropsychological performance received little support from the data. While none of the player characteristics correlated significantly with the NEURO factor, an important component of the hypothesis was supported by the relatively strong correlation between aggression and the heading index (r = .41, p = .002), a product of per game heading estimates and the weighted player index. The correlations between those variables emphasized by the hypotheses are presented in Table 3.

Because of the large number of variables included in this study, it was impractical to present all of the statistically significant correlations in the results section. Our analysis focused only on those relationships that were illustrated by observable patterns in the correlation matrix. Recognizing the possibility that our investigation was incomplete or biased in any way, the matrix is presented as an appendix.

Players who considered themselves more aggressive were not only more likely to provide higher estimates of heading, but also considered themselves to be more skilled at heading (r = .48, p = .000), more athletic (r = .39, p = .004), and better all-around players (r = .46, p = .001). Those players that labeled themselves as headers reported that they headed the ball more frequently per game (r = -.55, p = .000), were more aggressive (r = -.43, p = .001), and were more skillful headers (r = -.62, p = .000), but were not more likely to play in the center of the field. Players who were positioned in the center of the field had higher weighted playing index scores (r = -.31, p = .03), meaning they had more competitive experience. They also considered themselves to be more skilled all-around (r = -.53, p = .000), more athletic (r = -.56, p = .000), and better all-around players (r = -.46, p = .000). However, they did not report heading the ball more often, playing more aggressively, or suffering more soccer related head injuries than players positioned on the wings.

The only variables that correlated significantly with the NEURO factor were the number of years played (r = .30, p = .03) and the weighted playing index (r = .44, p = .001). Even when viewing partial correlations with age and education controlled, the substantial relationship between test performance and years played (r = .33, p = .02) and the weighted playing index (r = .43, p = .002) remained, suggesting that longer and more competitive soccer histories are related to lower levels of performance on the neuropsychological measures utilized in this study. These findings are consistent with the existing body of research and provide additional evidence that the game of soccer is somehow related to the neurological changes and neuropsychological deficits found in its more experienced and competitive players.

Discussion

Although many of the more elaborate predictions resulting from the positional theory and the hypothesized relationship between head injury, aggression, and neuropsychological performance were not supported by the data, several notable associations were established that should influence future research in this area. While position did not have any direct relationship with the measures of heading frequency, head injury, aggression, or neuropsychological measures, centrally located players varied from wing players on several important characteristics, including higher weighted index scores. Most importantly, the three measures of heading (header vs. non-header, heading frequency per game, and the heading index) and aggression correlated with relative strength ($r > .4$), statistical significance ($p \leq .002$), and in the hypothesized direction. Although the numbers did not reach statistical significance, it should also be noted in Table 3 that aggression did appear to show some relation to soccer head injuries ($r = .24$, $p = .08$) and the NEURO factor ($r = .25$, $p = .07$). Because aggression on the field is likely to be linked to soccer related head injuries and perhaps even behavior off the field, it is an important mediating variable that is essential to future research in this area.

The results of this study also provide further confirmation that soccer players are likely to suffer traumatic head injuries during the course of their careers. The mean score of 1.43 on the soccer head injury index suggests that at least one Grade 1 concussion was the average for this sample, with several players being knocked unconscious multiple times on the soccer field. These numbers suggest that Tysvaer (1989, 1991, 1992) and Witol (1993) overlooked an important aspect of this research question in their investigations.

The current study expanded the research question by including previously overlooked elements and viewing head injuries in soccer players in a more comprehensive framework. However, this broader scope required retrospective, self-assessment of player characteristics and did not allow for precise measurement of key variables. This is perhaps most evident when looking at the nature of the variables that correlated with the NEURO factor. It is likely that the weighted index and years played were the most reliable pieces of interview information attained from subjects because they were easily recalled, objective facts. Unfortunately, it appears that the most consequential variables are the most difficult to measure. Heading frequency, aggression, and head injuries as they were assessed in this study and those before it, are highly susceptible to subjective interpretation and are extremely difficult to measure accurately over the course of a twenty year soccer career.

This study's primary contribution is the previously undocumented relationship between aggression and heading frequency. However, it is important to note that these data provide no causal information and the use of the correlational design demands a cautious interpretation of the results. This research is based on the hypothesis that aggressive players head more often and are also more likely to suffer from head trauma. However, it is possible that previously brain injured or cognitively impaired players, tend to head the ball more often, are more aggressive and likely initiate traumatic head contact, and/or provide inaccurate or inflated estimates on important measures. Only more tightly designed experimental studies that provide temporal information will begin to eliminate alternative explanations.

Because crucial variables are not reliably assessed and cause/effect relationships are unattainable in the retrospective, quasi-experimental design, this research question will likely necessitate prospective, longitudinal studies involving more precise measurement of subjects. Future studies utilizing detailed video of play and meticulous coding of heading and head trauma are more likely to delineate the effects of heading and incidental head injuries and may reveal a subtle interaction between the two.

Future studies are also likely to benefit from improved subject selection. This project relied on volunteers from many different teams from different geographic regions and the selection process may have affected the results in some unforeseen way. Ideally, future studies will enjoy the added advantage of intact subject pools, in much the same way the Jordan et al. (1996) had a captive group in their elite team.

This research endeavor adds new and pertinent information to the study of head injury in soccer players. Even with its methodological limitations, it emphasizes the importance of including aggression in future research and the need to examine both heading frequency and soccer related head injury in a prospective and more precise way. Without improved methodology and accurate measurement of player characteristics within a more comprehensive framework, the mechanism(s) responsible for the neuropsychological deficits and neurophysiological differences seen in soccer players will continue to elude us.

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Table 1

Correlations between Neuropsychological Variables

	GPB	PASAT	TMT-A	TMT-B	BD
GPB	1.00 (53) p = .	r = -.17 (53) p = .22	r = .17 (53) p = .23	r = .12 (53) p = .40	r = -.31 (53) p = .02
PASAT	x	1.00 (53) p = .	r = -.31 (53) p = .024	r = -.44 (53) p = .001	r = .30 (53) p = .03
TMT-A	x	x	1.00 (53) p = .	r = .35 (53) p = .01	r = -.36 (53) p = .008
TMT-B	x	x	x	1.00 (53) p = .	r = -.24 (53) p = .09
BD	x	x	x	x	1.00 (53) p = .

Table 2

Loading and Communality for NEURO Factor

	NEURO Factor	Communality
PASAT	-.73 $p = .000$	.54
TMT-A	.72 $p = .000$	.52
TMT-A	.73 $p = .000$	.53
BD	-.65 $p = .000$	.42

Table 3

Correlations relating to hypothesis

	AGGRESSION	HEAD INDEX	SOCCER HEAD INJURY	POSITION	NEURO FACTOR
AGGRESSION	1.0 (53) p = .	r = .41 (53) p = .002	r = .24 (53) p = .08	r = -.07 (53) p = .61	r = .25 (53) p = .07
HEAD INDEX	x	1.0 (53) p = .	r = .18 (53) p = .21	r = -.19 (53) p = .18	r = .14 (53) p = .31
SOCCER HEAD INJURY	x	x	1.0 (53) p = .	r = -.03 (53) p = .85	r = -.14 (53) p = .31
POSITION	x	x	x	1.0 (53) p = .	r = .01 (53) p = .92
NEURO FACTOR	x	x	x	x	1.0 (53) p = .

Correlation Appendix

Two-tailed Pearson correlations with p values below .05 are bolded. N size for each correlation is 53.	Block Design	Paced Auditory Serial Addition Test	Pegboard	Trails A	Trails B	Neuro Factor	Age	Education	Header vs. Non-header	Heading Frequency	Heading Index	Head Injury	Number of Seasons	Player Index	Position	Soccer Head Injuries	Weighted Index	Aggression	All Around	All Around Skill	Athletic Ability	Heading Skill	Years Played
Block Design	1.00	**0.30**	**-0.31**	**-0.36**	-0.24	**-0.65**	-0.16	-0.07	0.15	-0.23	-0.26	0.18	**0.35**	-0.24	0.14	0.20	**-0.30**	-0.19	-0.16	-0.23	-0.12	**-0.28**	**-0.28**
Paced Auditory Serial Addition Test		1.00	-0.17	**-0.31**	**-0.44**	**-0.73**	-0.21	-0.14	0.05	0.01	-0.09	-0.02	0.19	**-0.31**	-0.01	0.07	**-0.32**	-0.22	-0.10	-0.11	-0.14	-0.11	**-0.35**
Pegboard			1.00	0.17	0.12	0.27	-0.05	0.01	-0.08	0.21	0.22	-0.08	-0.16	**0.38**	-0.07	-0.14	0.27	0.06	-0.06	0.01	-0.16	0.05	0.18
Trails A				1.00	**0.35**	**0.72**	0.10	0.06	0.01	0.02	0.11	0.09	0.05	**0.36**	0.07	0.00	**0.36**	0.19	0.05	0.17	-0.09	0.10	**0.32**
Trails B					1.00	**0.73**	0.03	**0.27**	0.10	-0.14	-0.04	0.01	-0.13	**0.24**	0.08	-0.14	**0.27**	0.11	-0.11	-0.05	0.09	0.12	-0.09
Neuro Factor						1.00	0.18	0.19	-0.03	0.02	0.14	-0.02	-0.21	**0.41**	0.01	-0.14	**0.44**	0.25	0.07	0.16	0.09	0.21	**0.30**
Age							1.00	0.22	-0.22	-0.06	-0.01	-0.03	-0.21	0.14	0.06	-0.07	0.13	0.04	-0.04	0.00	0.06	0.06	**0.56**
Education								1.00	0.03	-0.02	0.02	-0.11	-0.26	0.07	**0.30**	**-0.28**	0.08	-0.16	-0.27	-0.20	-0.20	-0.08	-0.15
Header vs. Non-header									1.00	**-0.55**	**-0.40**	0.02	0.04	-0.08	0.06	-0.23	-0.01	**-0.43**	-0.13	-0.03	-0.23	**-0.62**	-0.11
Heading Frequency										1.00	**0.91**	0.06	0.09	0.22	-0.13	0.21	0.18	**0.41**	0.13	0.17	0.16	**0.61**	0.01
Heading Index											1.00	0.07	0.09	**0.47**	-0.19	0.18	**0.47**	**0.41**	0.24	0.27	0.14	**0.58**	0.10
Head Injury												1.00	0.12	0.10	-0.04	**0.75**	0.12	0.13	0.22	0.18	0.16	0.04	-0.04
Number of Seasons													1.00	0.06	-0.05	0.15	-0.01	0.02	0.13	0.21	0.05	0.12	0.12
Player Index														1.00	-0.27	0.02	**0.94**	**0.30**	**0.39**	**0.44**	0.18	**0.45**	**0.40**
Position															1.00	-0.03	**-0.33**	-0.07	**-0.46**	**-0.53**	**-0.56**	-0.21	-0.14
Soccer Head Injuries																1.00	-0.01	0.24	0.17	0.11	0.04	0.22	-0.04
Weighted Index																	1.00	0.26	**0.47**	**0.50**	0.23	**0.43**	**0.35**
Aggression																		1.00	**0.46**	0.21	**0.39**	**0.48**	0.15
All Around																			1.00	**0.82**	**0.53**	**0.44**	**0.33**
All Around Skill																				1.00	**0.44**	**0.44**	**0.42**
Athletic Ability																					1.00	**0.36**	0.08
Heading Skill																						1.00	0.18
Years Played																							1.00