INVESTIGATING NEUROPSYCHOLOGICAL DYSFUNCTION IN SOCCER PLAYERS.

QUENTIN GEORGE WELDON

A Dissertation submitted to the Faculty of arts of the University of the Witwatersrand, Johannesburg, in fulfilment of the requirements of the degree of Master of Arts (Research Psychology). Johannesburg 1998

DECLARATION

I declare this dissertation is my own, unaided work. It is being submitted for the degree of Master of Arts, University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.

Signed: ____________

On: 9 MARCH 1998

ACKNOWLEDGEMENTS

1. Thank you to my supervisot, Mrs Patricia Jansen for great and valuable assistance and patience in guiding me through the murky waters of this thesis. Your contribution cannot be undervalued.
2. To all the boys who took part as subjects in this study, your generosity and time was greatly appreciated.
3. Thank you to all those parents, coaches and teachers whose co-operation was essential to the success of this study. Most notably I must show appreciation for Mr Willie Castle at St David's Preparatory School, Mr Robert de Beer at Bryandale Primary School, Mr Parnell at St Peter's Preparatory School, Mr Len Venter from Mark's Parkhurst Football Club, Mr Peter Gallagher from Wits University Football Club, and Mr John Lathan from the senior Wits football team. To all the parents who allowed me to test in your homes, your patience is greatly appreciated.
4. To Mr Peter Fridjohn from the Statistics Department of the University of the Witwatersrand for assistance in revising the design of the study, as well as in selecting the additional statistics to make the results most lucid.
5. To Messrs Mark Paiker and Eugenius Senaoana for great assistance in processing the statistics of this study, as well as for giving pointers as to how to interpret them.
6. To Dr Ismail Jakoet from the South African Rugby Football Union, for hospitality in providing me with valuable information.
7. To Mr Hilton Tanchum, Miss Natalie Wilson and Miss Melany Constantinou for assistance in the administration of some of the tests, as well as to my former employer, Dr Nicolas Christodoulou, for allowing me time when I needed it to work on this study.
8. To my parents and friends who gave me generous support over the time it took to complete this study.

ABSTRACT

This study sought to investigate the incidence and severity of disruptions of cognitive functioning in children following exposure to soccer play. A group of 49 soccer players (who are subdivided into club players and school players, the latter constituting a quasi-control group) and a group of 21 non-soccer playing control subjects were assessed three times over the course of a soccer season of approximately six months in duration. A battery of neuropsychological tests was used that was compiled to elicit practice effects from the subjects, as the hypothesis of the study was that exposure to soccer play may reduce the practice effects owing to repeated minor head trauma suffered on the field of play. On some of the tests in the study, such a reduction in practice effects was noted, although this reduction did not always tend to discriminate control subjects from soccer playing subjects. The club soccer players mostly performed slowest on the tests requiring most cognitive processing.

TABLE OF CONTENTS:

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1.

INTRODUCTION

Sport is a very physical activity and as such the participant in any sport runs the risk of sustaining a form of injury. The parts of the body most likely to be injured are those that are most utilised by the participant in the sport. These are likely to be injuries of the muscles, ligaments and bones of the limbs, back and torso. Some sports may pose more of a risk to certain parts of the body than do others. For example, weight lifters generally wear kidney-belts to protect their lower back and kidney areas.

Injuries are intrinsically likely to differ in severity depending on the circumstances surrounding how the injury was sustained. Prior injuries are likely to predispose a sport participant to further, aggravated injuries. Injuries would also differ in terms of how serious their repercussions would be on the person. Possibly the most serious injury a participant in sport may sustain is a head injury, particularly of a high degree of severity, given the implications thereof on the participant's future cognitive functioning.

Mild head injury in sport has been investigated by Barth, Alves, Ryan, Macciocchi, Rimel, Jane, and Nelson *et al.* (1989), who make the point that in most sports, great efforts are made to evaluate and eliminate the potential for what is viewed as **significant or severe** head trauma (their emphasis). This has not, however, been the case with most sports-related **mild** head injuries (their emphasis). Wilberger (1993) has found that the most common head injury in sports is the minor head injury or concussion - estimated to occur at a rate of 250 000 per year in contact sports. Association football, or soccer, is a contact sport, but is one of the sports in which to date little research has been done to determine the effects of mild head injury on its participants. However, Schneider and Zernicke (1988), have expressed concern over the potential for head injury in soccer.

Soccer is a very popular spectator and participant sport. In 1989, there were over 40 million registered players alone world-wide (Tysvaer and Storli, 1989), and these figures were confirmed in 1992 (Dailey and Barsan, 1992). Subsequent studies have suggested an increase in the popularity in soccer since the World Cup tournament held in the USA in 1994 to approximately 42 million (Jordan, Green, Galanty, Mandelbaum and Jabour (1996). Like most sports, soccer poses a risk of injury to its participants, although the risk of serious head injury should not be as great as in sports such as boxing. Most soccer-related injuries would involve bruises, lacerations, muscular strains and sprains, torn ligaments and occasionally broken bones, and the areas of the body most affected would be the legs (particularly the knees) and groin. But since players' heads come into contact with the ball, and there is a chance of high speed collisions (including clashes of heads) and rotational injuries. These may place soccer players at risk of suffering subtle impairment of neuropsychological functioning.

The plastic-coated football that is currently used by soccer players has when inflated a weight of between 396 and 453 grams (Smodlaka, 1984) and a kicked football can reach speeds of 60 to 120 km/h (Fields, 1989). Adams (1976) suggests that soccer players are more aware of the likelihood of sustaining blows to the head than are rugby players, and are consequently more prepared to receive blows to the head in such a way as to minimise the risk of injury, than are their counterparts in rugby. But is this foreknowledge sufficient when the player is required to head a ball weighing 450 grams and travelling at the speeds mentioned above?

The current study will explore the incidence of head injury in soccer, and investigate the incidence of head injury-related symptoms, which may not necessarily follow a concussive injury. The study will investigate the evidence obtained thus far in sports-related neuropsychological and neurological research. Other sports that are termed "contact sports" will be considered, as well as theories of mild head injury in children and in sports participants. Concerns regarding head injuries in sport, such as the second impact syndrome, and the guidelines for returning to sport participation will be considered.

The literature review will consider the aspects of mild head injury in terms of its causes and effects, as well as considering mild head injury in the relevant populations, i.e. sports participants and children. In the third chapter (Research Methodology) there is a discussion of the aims, hypotheses and research questions, as well as the rationale behind the choice of subjects and test materials. Procedural considerations are also discussed in that chapter. Thereafter in Chapter 4 the results will be presented and briefly summarised, ant these will be discussed in Chapter 5. Chapter 6 concludes the dissertation and considers limitations of the study as well as future implications.

CHAPTER 2.

LITERATURE SURVEY

2.1. Closed Head Injury

Closed head injury results in two categories of injury: primary and secondary (Pang, 1989). Primary injury occurs instantaneously at impact, and is usually permanent. It does not respond to therapeutic measures, and generally constitutes the limiting factor for neurological recovery. Primary injuries may take two forms (McLatchie & Jennett, 1994), of which contusions are the commonest, and divided into two types: **focal** underneath the fracture resulting from focal impact, be it blunt or penetrating; and **diffuse** usually following deceleration of the head (ibid.). The other form of primary injury involves diffuse axonal injury, which consists of widespread tearing of white matter fibres in subcortical areas of the brain. This may occur without pronounced contusions or a fracture of the skull, and it usually causes immediate unconsciousness (McLatchie and Jennett, 1994).

Secondary injury occurs as a result of epiphenomena causally related to the primary injury, such as oedema or brain swelling resulting from vascular engorgement, and acute intracranial haematoma (McLatchie and Jennett, 1994; Pang, 1989). These epiphenomena may result in an increase in intracranial pressure, and cause brain shift and cerebral ischaemia, which in turn produce further c[illegible]ions such as hypoxia (lack of oxygen to the brain). Intracranial infection is also l[illegible] when the dura mater is penetrated. Hypoxia and ischaemia are only likely in a sporting sense when the whole body has suffered violence, such as in climbing, horse-riding, or motorsport-related accidents (McLatchie and Jennett, 1994). Management of head injuries affects outcome through minimisation of occurrence of the secondary brain injuries as opposed to repair of the primary injury (Pang, 1989).

Primary brain injury can be induced by both acceleration-dependent and nonacceleration-dependent mechanisms (Pang, 1989). Forces that produce acceleration to the head tend to generate much more severe brain injury than equivalent forces delivered to the fixed skull (ibid.), with studies showing a blow of moderate intensity to a moveable head inducing devastating cerebral contusion, and a blow twenty times as strong causing extensive fractures but remarkably little neurological deficit (ibid.).

Parker and Rosenblum (1996) define traumatic brain injury as a process in which neurobehavioural dysfunctions change over time, and therefore add two more classifications of brain injury to the aforementioned two, namely tertiary and quaternary injuries. Tertiary brain injury includes late physiological effects, a lack of physiological development of children due to damage to the hypopituitary-thalamic axis, impaired homeostasis (compensatory adjustments to meet any threat to the personality) and impaired brain autoregulation. Quaternary brain injuries are longer-term injuries and include late neurological symptoms that occur years later such as premature senility and dystonia, post-traumatic epilepsy, and premature cognitive ageing. It would seem that tertiary injuries are important with regard to the present study, since the subjects in this study would be entering a critical stage of cognitive as well as educational development in the next four to five years after their present stage of development. At present they would be in their eleventh year, and therefore approaching the end of Elementary School education.

Traumatic brain injury is determined by factors that include the point of impact and its direction, velocity, and accelerating or decelerating effect; whether the neck is braced; whether the rotation is accelerated or steady; the relative strength of the head-neck junction; the ratio of brain mass to injuries affects outcome through minimisation of occurrence of the secondary brain injuries as opposed to repair of the primary injury (Pang, 1989).

Primary brain injury can be induced by both acceleration-dependent and nonacceleration-dependent mechanisms (Pang, 1989). Forces that produce acceleration to the head tend to generate much more severe brain injury than equivalent forces delivered to the fixed skull (ibid.), with studies showing a blow of moderate intensity to a moveable head inducing devastating cerebral contusion, and a blow twenty times as strong causing extensive fractures but remarkably little neurological deficit (ibid.).

Parker and Rosenblum (1996) define traumatic brain injury as a process in which neurobehavioural dysfunctions change over time, and therefore add two more classifications of brain injury to the aforementioned two, namely tertiary and quaternary injuries. Tertiary brain injury includes late physiological effects, a lack of physiological development of children due to damage to the hypopituitary-thalamic axis, impaired homeostasis (compensatory adjustments to meet any threat to the personality) and impaired brain autoregulation. Quaternary brain injuries are longer-term injuries and include late neurological symptoms that occur years later such as premature senility and dystonia, post-traumatic epilepsy, and premature cognitive ageing. It would seem that tertiary injuries are important with regard to the present study, since the subjects in this study would be entering a critical stage of cognitive as well as educational development in the next four to five years after their present stage of development. At present they would be in their eleventh year, and therefore approaching the end of Elementary education.

Traumatic brain injury is determined by factors that include the point of impact and its direction, velocity, and accelerating or decelerating effect; whether the neck is braced; whether the rotation is accelerated or steady; the relative strength of the head-neck junction; the ratio of brain mass to head mass; the duration of the impact impulse; and the characteristics of the scalp (Parker and Rosenblum, 1996).

Acceleration injuries are divided into two types, translational and angular (Pang, 1989). The former may be described as linear, and are produced by a force vector applied through the centre of gravity of a rigid body, and no intermolecular stress is sustained since all individual particles within this body travel at the same acceleration and in the same direction (ibid.). If the force vector does not pass through the centre of gravity of a body, the body will rotate around its own centre of gravity and assume an angular acceleration (ibid.). Most impact forces produce a combination of translational and angular acceleration, and result in shearing injuries (Pang, 1989). This would suggest that translational acceleration would result in more focal coup (situated beneath the site of impact) and contre coup (lesions at some distance from the site) injuries, while angular acceleration is more likely to result in diffuse injuries.

Traumatic brain injury needs only sufficient angular rotation (without impact) to occur (Parker and Rosenblum, 1996). Rear-end impact causes the head on the relaxed neck to be left behind momentarily, while front-end collision causes the head to be propelled forward. The head moves in a combination of planes (lateral and sagittal) and torsion around the tethering neck, which changes the brain's position and movement relative to the enclosing skull and often causes impact within the confining space. Parker and Rosenblum (1996) contend that it is unpredictable which structures will be over-stressed and damaged, and postulate that reduced concentration and memory are compatible with damage to basal frontal and upper brainstem activities.

In terms of primary injuries, soccer players' heads are more likely to be accelerated than fixed, although the speed of impact is not likely to be substantial, especially when compared to the commonly found acceleration and deceleration of the head that occurs during motor vehicle accidents.

2.2. Mild Head Injury

Rutherford (1989) takes issue with the term minor (mild) head injury, in that it is not confined to brain injuries, but refers also to facial wounds, or dislocation of the jaw, *inter alia*. He proposes the term "concussion" and defines it as follows:

Concussion is an acceleration/deceleration injury to the head almost always associated with a period of amnesia, and followed by a characteristic group of symptoms such as headache, poor memory, and vertigo.

Concussion has been contrasted with contusion, lacerations and haemorrhage, where the lesion could be clearly seen (Tan and Kakular, 1981), although Oppenheimer (1968) has demonstrated microscopic damage to be present. Rutherford (1989) maintains that all acceleration/deceleration injuries, regardless of severity, result in the same type of brain damage, and all the symptoms following the mild cases are seen in the major cases also.

Walsh (1987) defines a simple concussion as a brief clouding or temporary loss of consciousness, and he postulates that this is probably due to injury to the brain-stem reticular formation.

Beers (1992) defines a concussion as occurring with a disruption of neurological function caused by a blow to the head or a rapid acceleration and deceleration. Loss of consciousness is not always present, which is confirmed by Jennett (1989) who claims that impairment of consciousness is indicative of diffuse brain damage, but there can also be marked local damage without either alteration in consciousness or amnesia. Beers (1992) claims that an extremely mild head injury may produce cognitive and/or information processing deficits that manifest as failure to benefit from practice effects that can be demonstrated through neuropsychological assessment within 24 hours of injury.

2.2.1. Severity of Concussion

Concussion has been graded in terms of severity into mild, moderate and severe, and although this grading system is not ideal (van Veldon, 1990), it is useful in terms of triggering a safe clinical approach to concussion.

Grade I (mild) concussion may not present with obvious signs. There may be a brief period of slight mental confusion, some dizziness, minimal unsteadiness, and a brief loss of judgement, typically with no loss of consciousness (Reid, 1992). Not clearly remembering recent events and difficulty interpreting new information are considered the hallmarks of this level of concussion (Yarnell and Lynch, 1973).

Grade II (moderate) concussion is characterised by a transitory loss of consciousness of up to five minutes (van Veldon, 1990; Reid, 1992). Subsequent mental confusion, dizziness of a moderate severity and at times a transient headache are reported. Minimal retrograde amnesia is evident, which has been noted to be persistent for a significant period post-injury (Reid, 1992).

Grade III (severe) concussion produces a period of unconsciousness of more than two minutes (Reid, 1992; Yarnell and Lynch, 1973). Prolonged and significant retrograde amnesia may follow this type of injury.

2.3. Major causes of Mild Head Injury.

Five major causes of mild head injury have been identified   he following (in order of frequency)

1. Motor vehicle crashes (sic) - victims including occupants of the vehicle, motorcyclists, bicyclists and pedestrians.
2. Falls
3. Assaults
4. Cycling accidents not involving motor vehicles
5. Sports and recreation injuries. (Kraus and Nourjah, 1989)

The incidence of these injuries varies with age and gender distributions, as well as with times of injury (Kraus and Nourjah, 1989), with eighty per cent of the mild brain injury diagnoses in this study comprising concussion. Brain injuries from recreation or sports activities are generally higher for males than for females (ibid.). More important for this study, however, is their finding that the sport-related injury rates for males peak between the ages of 10 and 14 years (Kraus and Nourjah, 1989). The distribution of times of brain injuries shows that brain injuries from sports and recreation activities do not display a pronounced weekend excess in terms of distribution, unlike assaults and motor vehicle accidents, which occur primarily on weekends.

2.3.1. Classifying Mild Head Injury

Jennett (1989) argues that the definition of mild head injury is problematic, and that the Glasgow Coma Scale has limited use in this regard, since it is not intended as a means of distinguishing among different types of mild head injury. The Glasgow Coma Scale (G.C.S.) score examines three areas of behaviour: eye opening, response to voice and motor responses (Australian National Health and Medical Research Council, 1993, henceforth referred to as N.H.M.R.C., 1993). The degree of spontaneity of these behaviours determines the score, with more spontaneous responses scoring higher. The score can therefore be quantitative, with 3 being the lowest score and 15 normal, while a score of 8 or less implies a severe head injury. Since many patients are orientated by the time they are first assessed, they are likely to score at the top of the G.C.S. (Jennett, 1989), i.e. between 13 and 15. Yet some post-concussive patients have had a period of altered consciousness (which is an additional means of evaluating the severity of head injury), either witnessed or evidenced by their being amnesic for events immediately following injury (Jennett, 1989).

2.3.2. Post-Traumatic Amnesia (PTA)

The term post-traumatic amnesia refers to any disturbance of memory for events that occur in the period immediately following head injury (Ruff, Levin, Mattis, High, Marshall, Eisenberg and Tabaddor, 1989). It is recognised as one of the most distinctive markers of closed head injury, and is frequently encountered in patients with mild head injury (Ruff et al., 1989). Patients are characteristically disoriented and demonstrate confusion. Anterograde memory seems most affected in these cases (Ruff et al., 1989). PTA has been demonstrated to last from a few minutes to several hours, although inconclusive results have been found on neuropsychological studies on the subject (Barth, Macchiochi, Boll, Giordani, Jane and Rimel, 1983; Gentilini, Nichelli, Schoenhuber, Bortolotti, Tonelli, Falasca and Merli, 1985; Dikmen, McLean and Temkin, 1986).

The concept of PTA has evolved over the years, initially using the length of time from injury to the time when the patient became aware that he had regained consciousness (Walsh, 1987). This was later modified to include anterograde amnesic conditions. Newcombe (1982) cautions that there is no simple relationship between length of PTA and severity of defect. Therefore length of PTA is not a reliable indicator of severity of injury, since some individuals who appear to demonstrate lengthy PTA have been found to manifest little impairment, while others who were perceived as having had shorter PTA have been left with considerable deficit (Walsh, 1987).

2.4. Effects of Mild Head Injury

2.4.1. The Post-Concussion Syndrome

Mild head injuries exhibit more subtle symptoms than most people would associate with damage to the brain. These symptoms include headaches, dizziness, nausea, diplopia, tinnitus, personality change (particularly irritability), attentional deficits, and information processing impairment (Barth et al., 1989). Leininger, Gramling, Farrell, Kreutzer, and Peck (1990) report that minor head injury patients who report post-concussive symptoms possess measurable neuropsychological deficits, and the severity of these deficits is independent of the neurological status of the patient immediately following the injury.

Headaches and dizziness are typically the most prominent components of this syndrome (Wilberger, 1993). Headaches tend to be diffuse and aggravated by movement, anxiety and stress, while the dizziness is usually described as a feeling of unsteadiness exacerbated by movement and changes in position (ibid.). Carlsson, Svärdsudd, & Welin (1987) found a strong correlation between the degree and extent of post-concussive symptoms and the number of previous head injuries, and conjectured that the cumulative effects of repeated head injury play a significant role in this syndrome.

Research indicates that information processing ability is more severely affected and takes longer to recover in patients after second or third concussive injuries than in patients with a single mild head injury (Gronwall & Wrightson, 1975). **Information processing capacity** can be described as the number of operations the brain can carry out at the same time (Gronwall, 1989), and after mild head injury, patients have difficulty in all areas that require them to analyse more items of information than they can handle simultaneously.

The residual effect that follows apparent full recovery after a mild head injury has been shown to result in increased vulnerability to a second CNS stressor (Ewing, McCarthy, Gronwall and Wrightson, 1980). As a result, doctors recommend that following three repeated concussions, participation in the offending activity should be discontinued (Barth et al., 1989). Shuttleworth-Jordan, Balarin and Puchert (1993) suggest that this may be too late.

2.4.2. Duration of post-concussive symptoms.

Rutherford (1989) argues that "postconcussion" symptoms would be more accurately termed "concussion symptoms", and distinguishes early and late concussion symptoms. However, for the purposes of clarity in this dissertation, the term post-concussive symptoms will be retained. Early symptoms are those of which the patient complains immediately after regaining full consciousness, as well as on the morning after the injury. These include headache, dizziness, vomiting, drowsiness and blurred vision. Late symptoms overlap to a degree with early symptoms, but may last up to three years post-trauma. Irritability, anxiety, depression, memory and concentration difficulties and insomnia are examples of late symptoms (Rutherford, 1989; Batchelor, Harvey and Bryant, 1995).

Mild head injury patients tested at 3 months post-trauma performed more poorly on interference tests, such as the modified Stroop Word-Colour test, compared to control subjects (Bohnen, Jolles and Twijnstra, 1992). Patients with lingering post-concussive symptomatology were found to be slower on interference conditions than concussion patients who were subjectively well recovered (Bohnen, Twijnstra and Jolles, 1993). This included sports accident victims.

2.5. Mild Head Injury and Children

Jennett (1989) reports that children of less than 15 years comprise a larger proportion of mild than severe injuries. Neuropsychological testing on children who have suffered traumatic brain injury has indicated that continuing, serious post-traumatic intellectual impairments remain long after electroencephalograms and neurological examinations have returned to normal (Fuld and Fisher, 1977). Personality changes were found to have occurred to some extent, although these appear to have disappeared after cognitive, language and motor functions had improved (Fuld and Fisher, 1977). Adams (1990) also points out that, "following mild head injury, persistent cognitive deficits remained long past the expected 3-month recovery period. The most apparent deficits were found on a complex mathematics task requiring reading, calculation and novel problem-solving."

Children and young adults make up more than 50% of all new head injury cases, with incidence rates estimated between 185 and 230 per 100 000 population for children 14 years of age and younger (Greenspan and MacKenzie, 1994). Regardless of head injury severity, head injured children are more likely to have limitations in physical health, have a greater number of behavioural problems and be enrolled in a special education programme than children from the general population (Greenspan and MacKenzie, 1994), which was ascertained up to a year post-injury. Greenspan and MacKenzie (1994) found greater functional limitations for children with minor to moderate head injuries (as classified on the Glasgow Coma Scale and Abbreviated Injury Scale) than was previously reported. They conclude that though children with minor or moderate head injuries may not exhibit any frank neurological signs, they may demonstrate minor limitations, that although not clinically apparent, nevertheless may affect the children's daily function and performance.

An important finding of Greenspan and MacKenzie (1994) is that socio-economic disparities may have an impact on pre-injury functioning, and that children from poor or near-poor families, and those with lower extremity injuries or pre-injury chronic health problems may be at risk of impairment. Since the present study sought to test athletically inclined children, chronic health problems are perhaps less likely to be a factor, as children with chronic health problems are less likely to play sport, especially competitive sport. Children with lower extremity injuries are also unlikely to participate in soccer. However the current study comprised children of a middle-to-higher socio-economic bracket, and future studies may seek to investigate neuropsychological dysfunction in people belonging in different income brackets.

Chadwick, Rutter, Brown, Shaffer, and Traub (1981) report that the test performances most affected after head injury in children are those dependent upon the child's ability to respond quickly, particularly on tasks requiring motor responses. However, this referred to head injury in general, and was not confined to mild head injury.

Levin, Ewing-Cobbs and Fletcher (1989) caution that test-retest intervals as brief as six months may normally be associated with improved performance on cognitive and memory tests, owing to maturational changes (apart from the practice effects, which accrue from repeated testing in adults) whereas a relatively stable cognitive level may be assumed in neurologically normal adults. This would suggest that improvement in performance over time is attributable to two factors, which are likely to be mutually reinforcing.

2.6. Head injury and Sports Participants

Most sport-related injuries are musculoskeletal, affecting the limbs or the trunk and related to specific risks associated with particular sports (McLatchie and Jennett, 1994). Head injuries by contrast can occur in many sports, and, except for those incurred during boxing, are accidental (ibid.). Unlike other injuries, the effects of which are usually maximal at onset, injuries to the head may precipitate a process of intracranial disorder that can convert a mild initial injury into a life-threatening condition from secondary complications. Moreover, even mild injuries are often associated with considerable temporary disability and repeated mild injuries can result in cumulative brain damage (McLatchie and Jennett, 1994).

Sport-related head injury accounts for approximately one tenth of all head injuries presenting to hospitals and specialised neurosurgical units (Lindsay, McLatchie and Jennett, 1980). Mostly the patients referred to neurosurgical units have sustained more serious injuries (N.H.M.R.C., 1993).

If a player sustains a concussion during the course of a sport session, be it practice or match, he would be expected to show deficits in performance and reduced learning effect, possibly even regression in performance until the effects of the concussion have worn off. Psychometric tests have shown clear evidence of impaired information processing for two to three weeks after injury (Shuttleworth-Jordan et al.,1993). Shuttleworth-Jordan et al. (1993) reported similar findings with rugby players, even finding that some neuropsychological impairment may be present for as long as three months after injury. For this reason, sports administrations impose varying time periods for recovery following injuries on the players associated with the code (N.H.M.R.C., 1993).

Barth et al. (1989) postulate that athletes typically do not complain about the symptoms associated with "minor injuries" because doing so would be a sign of weakness, and worse, might result in elimination from participation in upcoming competition. This may result in the incidence of such injuries being reported being lowered, and it may be that these injuries are more widespread than has been reported to date. It is postulated that children would be as reticent about disclosing the symptoms associated with minor head injuries to their coaches as adults would, particularly those children who regarded participation in games as very important. Alternatively, with the world-wide increase in professionalism in sport, it may be that adult sports participants who have incurred minor injuries are not likely to report them, as elimination from competition would disrupt their livelihood.

2.6.1. Second Impact Syndrome

Repeated minor head injuries occurring in short succession may result in a fatal outcome (Wilberger, 1993). This is known as the Second Impact Syndrome, and it is generally felt that this syndrome occurs because of a sensitivity of the cerebral vasculature induced by the first injury. The second injury would lead to autoregulatory dysfunction, cerebral vascular congestion and subsequent intracranial hypertension, and potentially to death. Kelly, Nichols, Filley, Lillehei, Rubinstein, and Kleinschmidt-DeMasters (1991) emphasise that this syndrome may occur even in the setting of a mild head injury with no loss of consciousness.

The typical pattern of Second Impact Syndrome in a sporting sphere starts with postconcussive symptoms, including visual, motor or sensory changes and difficulty with thought and memory (Cantu and Voy, 1995). Before these symptoms resolve the athlete returns to competition and receives a second blow to the head. This second blow may be remarkably minor, perhaps involving a blow to the chest, side or back that can "snap" the athlete's head and impart accelerative forces to the brain (Cantu and Voy, 1995). The athlete may appear stunned, but usually does not lose consciousness. Within the period from about 15 seconds to several minutes of the second impact the athlete, initially conscious though stunned, quite precipitously collapses with rapidly dilating pupils, loss of eye movement and respiratory failure.

The aetiology of Second Impact Syndrome is thought to be a disruption of the brain's blood autoregulatory system (Cantu and Voy, 1995). Vascular engorgement within the cranium markedly increases intracranial pressure and gives rise to herniation. The usual time from the second impact to brain stem failure is rapid, usually two to five minutes.

2.6.2 Classifying mild head injury in sports participants

Several attempts have been made to classify cerebral concussion in athletes (Barth et al.., 1989). Nelson, Jane and Gieck (1984) have postulated a concussion classification system for sports participants that would focus on five grades of mild head injury, from grade 0, indicating no loss of consciousness but confusion and subsequent difficulty concentrating, to grade 4, characterised by loss of consciousness for more than one minute (yet no coma), headache, cloudy sensations, possible irritability, confusion and dizziness during recovery. Cantu and Voy (1995) utilise the three grade system, and propose the following symptoms and measures for sports physicians.

CONCUSSION SEVERITY SCALE (Cantu and Voy, 1995)

Grade	Symptoms
1. (mild)	No loss of consciousness. PTA of less than 30 minutes.
2. (moderate)	Loss of consciousness of less than 5 minutes or PTA greater than 30 minutes but less than 24 hours.
3. (severe)	Loss of consciousness of 5 minutes or more or PTA of 24 hours or more.

On the basis of these definitions, they have established the following guidelines for head-injured American football players in terms of resuming their participation in the sport.

GUIDELINES FOR RETURNING TO FOOTBALL PLAY AFTER CONCUSSION

(Cantu and Voy, 1995)

Grade	First Concussion	Second Concussion	Third Concussion
1 (Mild)	Return to play if asymptomatic	Return to play in 2 weeks if asymptomatic for 1 wk	Terminate season; may return to play next season if asymptomatic
2. (Moderate)	Return to play if asymptomatic for 1 wk	1 month minimum restriction; may then return to play if asymptomatic for 1 week; and consider terminating season.	Terminate season; may return to play next season if asymptomatic
3. (Severe)	1 month minimum restriction; may then return to play if asymptomatic for 1 week.	Terminate season; may return to play next year if asymptomatic	

As may be seen from these considerations, it is considered important for a sports physician to monitor post-concussive symptoms, as minor head trauma in a player who still has symptoms from a previous concussion may have extremely serious consequences. Leblanc (1994) provides almost identical guidelines to Cantu and Voy, but adds the necessity for a CT scan in addition to the observation of the individual being asymptomatic.

2.6.3 Paediatric Sports-related Head Injury

Genuardi and King (1995) consider the most important factor in preventing serious sequelae from a sports-related closed head injury to be an adequate amount of recovery time before returning to athletic participation. They found, however, that children who had been discharged from hospital following head injuries had been given inappropriate instructions about returning to their sports. This was most noticeable for children with grade III concussions, which given the possibility of Second Impact Syndrome, appears to be particularly negligent. They do concede, however, that an important issue in this regard is excessive pressure from both outside sources and young sports participants themselves to allow premature return to play. This was found even for junior high school and high school level children. This study was conducted in the USA, but there seems no reason to suggest that similar incidents have not taken place in South Africa.

2.6.4. High Risk Sports for Mild Head Injury

Certain sports are more prone to producing head injury. These are discussed below.

2.6.4.1. Boxing

In a sport such as boxing, the usual target of the blows that may result in injury is the head, as boxing seeks to render the opponent unconscious and helpless by means of successive blows to the head (Barth et al.., 1989). It stands to reason therefore that boxers are at risk of sustaining head injuries of varying degrees of severity.

Extrapolating from boxing findings, Lampert and Hardman (1984) have identified four types of injury to the brain likely to be sustained by sports participants. These are:

(1) Rotational acceleration: sudden acceleration of the head with subsequent rotational movement of the brain inside the skull, leading to the stretching and snapping of blood vessels.

(2) Linear acceleration: which may result in focal cerebellar ischaemic lesions.

(3) Carotid artery injuries: causing hypotension and dizziness due to diminished blood flow to the brain.

(4) Deceleration upon impact: which typically results in occipital coup and frontotemporal contre coup lesions.

The writer argues that (1), (2) and (4) would be most applicable to soccer players, with (3) being less plausible. This would be likely given the reduced likelihood of contact between the ball and the player's neck. With the prescribed heading technique in soccer, linear acceleration is more likely than rotational acceleration, although in high-pressure situations, faulty heading techniques may be employed resulting in rotational acceleration.

2.6.4.2. High-speed sports

Participants in equestrian sports are also at risk of head injury, head trauma being the most common and most severe form of sport-related injury to be sustained by these enthusiasts

(Bixby-Hammett, 1983). Riders who do not wear helmets are considered at additional high risk for sustaining significant head trauma (Barth et al.., 1989). Jockeys were found to be exposed to frequent and often unrecorded concussive head injury (Foster, Tilley and Leiguarda, 1976).

Other sports in which the participant is moving at high speed, such as the motor sports and even cycling require their participants to wear helmets in order to protect the head. Barth et al.. (1989) point out that competitive motorcyclists wore protective helmets long before the general population deemed it necessary to do so. Traditional winter sports, such as skiing, are included in this field (Barth et al., 1989), i.e. they place the participant at risk of sustaining head injury and also require participants to wear protective headgear.

2.6.4.3. Other codes of Football

Rugby football (League and Union) and American (gridiron) football are also noted as sports that are characterised by violence and hard contact between bodies (Shuttleworth-Jordan et al., 1993). Australian football (Australian Rules, or as it is colloquially known, "Aussie Rules") is also a sport in which concern has been raised regarding the possibility of head injuries (N.H.M.R.C., 1993).

American (Gridiron) football: The risk of serious head injury in American football is reflected by the fact that at all levels of the sport, participants are now required to wear protective helmets (Barth et al., 1989). Nevertheless, it has been estimated that in high school American football players, there is a 20% risk of minor head injury every year of play and that an athlete who has sustained one concussion is at a fourfold risk for sustaining repeated head injuries (Gerberich, Priest, Boen et al., 1975). Leblanc (1994) reports that head injuries account for approximately two-thirds of all direct deaths in American football, with the estimated incidence rate of head injury of high school football players being 250 000 concussions per year, despite regulations introduced into the game to reduce this risk.

Rugby football: The nature of rugby football is such that rugby players are exposed to head and neck injuries, and the risks involved in head-to-head contact in rugby appear to be greater than in gridiron since rugby players do not wear helmets (Shuttleworth-Jordan et al., 1993).

Rugby football is played at high speeds, and involves much stringent physical contact. It has been termed a collision sport, rather than a contact sport by the Australian National Health and Medical Research Council (1993). Players in rugby, particularly forwards, are susceptible to head injury when contesting for the ball, particularly in a ruck situation, where a number of players may fall on top of one another player, and kicks directed at the ball may (inadvertently or sometimes intentionally) strike a player on the head.

Incidence studies reveal that concussion accounts for the single most common injury in rugby (Nathan, Goedeke and Noakes, 1983; Roux, Goedeke, Visser, van Zyl and Noakes, 1983), and blows to the head and neck are responsible for most rugby-related on-field or off-field deaths. However, statistics obtained by the South African Rugby Football Union dispute this finding (S.A.R.F.U. injury statistics, 1994 and 1995, unpublished - personal communication), in that concussion accounts for six to ten per cent of injuries in rugby, and lags behind ligament strains, muscular strains, and lacerations in this regard. Despite these findings, it is certain that concussion may be considered one of the most serious injuries to the player.

The rugby players most prone to injury (as reported in South Africa and tabulated by the South African Rugby Football Union) are loose forwards, locks and prop forwards. Injuries come most frequently during tackles, in rucks and mauls, and in set scrums (S.A.R.F.U. injury statistics, 1994 and 1995). The nature of prop forward play in particular exposes the player to neck and head injuries in the set scrums.

In terms of the cognitive effects of head injury in rugby union, Shuttleworth-Jordan et al. (1993) report that the incidence of practice effects found when comparing pre-season and post-season assessments was greater in their control group than in their group of rugby players, suggesting that rugby players are sustaining some form of neuropsychological impairment. A **practice effect** is an improvement in performance following repeated exposure to the tests. The concept of the practice effect and more specifically any observed reduction of practice effects is central to this study. The battery of tests used in this study was designed to elicit practice effects, at least in the control groups.

2.7. Mild head injury and Soccer Players

Conflicting findings have been reported with respect to head injury and soccer players, and medical opinion is divided concerning this subject. The study by the N.H.M.R.C. (1993) reveals that concussion is less prevalent in soccer than in rugby (league and union) and Australian football. They do, however, caution that soccer may cause cerebral atrophy owing to repeated heading of the ball.

Soccer is considered to have a significantly low risk of head injuries, in spite of the fact that "heading the ball" is an essential part of the game (N.H.M.R.C., 1993). However, the procedure of heading the ball may expose the "header" to a risk of a clash of heads with another player competing for the ball (Dailey and Barsan, 1992). Concussion rates as calculated by the

American National Collegiate Athletic Association (N.C.A.A.) injury surveillance report for the 1993-94 sporting seasons are that men's soccer shows a concussion incidence of 0.15 per 1000 exposures, while women's soccer has a slightly higher incidence, *viz.* 0.16 per 1000 exposures (Cantu and Voy, 1995). This was compared to collision sports such as ice hockey (0.49) and American football (0.31). Kujala, Taimela, Antti-Poika, Orava, Tuominen and Myllynen (1995) found a lower rate of injuries, viz. 25 injuries per 1000 person years of experience in children under the age of 15 years, with the greatest risk being between the ages of 20 and 24 years. They also found that there was a bias toward being injured in competition (games) as opposed to during training, with a 56% to 44% ratio.

2.7.1. The football

The modern soccer ball is made of waterproof, synthetic leather covered with urethane (Dailey and Barsan, 1992). By repelling water, they decrease the possibility of adding weight to the ball and thus decrease the potential for injury (ibid.). However, Fields (1989) cautions that despite improvements in the construction of the ball, particularly the addition of a plastic coating, the ball remains a factor that may contribute to injury. On average, the ball travels at 23 metres per sec (approximately 80 kilometres per hour) and exerts an impact of 116 k.p.m, and wet conditions can add significantly to this impact, especially if the plastic coating has become badly worn (Fields, 1989). In addition, even correct heading of the ball can cause headaches that may last for several days (ibid.).

2.7.2. "Heading the ball"

Controlled head contact with the soccer ball, or heading, is considered as valuable a skill as shooting on goal with the feet (Dailey and Barsan, 1992). The football is generally "headed" with the frontal area of the skull, and when heading correctly, the ball is struck with the frontal bone. Muscle tension keeps the cervical spine rigid, and linear, as opposed to rotational acceleration is imparted to the ball. This does not apply if the ball is struck incorrectly or if the head receives a glancing blow. The football could impact the head at as much as 200 kP of pressure (N.H.M.R.C., 1993).

At senior level of soccer, players tend to have well-developed cervical strap muscles, and at all levels, tightening the muscles in the cervical area during the action of "heading the ball" appears to be responsible for the minimal number of neck injuries in soccer, since this would distribute the "shock" of the impact around the shoulder muscles (N.H.M.R.C., 1993).

Players head the ball on an average of six times in a match, and more often during training (Corrigan, Personal Communication to the N.H.M.R.C., 1993). Since players differ in the degree of their heading skill, some players will seek to head the ball more often than others. For example, a player in a defensive position may be required to head the ball more frequently than a player in a more advanced position on the field.

Mathews (1972) illustrated that classical migraine, including incapacitating visual field defects, repeatedly developed in five young men immediately after blows to the head arising from heading the ball and in no other circumstances. An isolated attack of classical migraine in young boys following a blow on the head at soccer is not uncommon (ibid.). It is unclear, however, to what extent the subjects of Mathews's study were trained in formal heading techniques, and faulty heading technique may have increased the severity of the injury where the risk would ordinarily have been minimal. Fields (1989) reports that a player who heads the ball with the neck flexed or extended may experience increased head motion, which has been cited as a critical factor in concussion.

2.7.3. Retrospective studies

Haglund, Edman, Murelius, Oreland, and Sachs (1990) failed to demonstrate any signs of serious chronic brain damage in soccer players who headed the ball, and Haglund and Bergstrand (1990) found no morphological brain changes in soccer players. However, there is speculation as stated previously (N.H.M.R.C., 1993) that chronic encephalopathy may occur in soccer players, with neuronal damage similar to that seen in the traumatic chronic encephalopathy of boxers, and which is assumed to be due to repeated heading of the ball.

Tysvaer and Storli (1989) reported significant incidence of electroencephalogram (EEG) disturbances among soccer players compared to non-soccer playing controls. They suggested that this was a result of repeated minor head traumas. However, Tysvaer, Storli and Bachen (1989) reported that there was no increased incidence of EEG disturbance in headers of the ball compared to players who do not head the ball. Tysvaer and Løchen (1991) report that neuropsychologic examination demonstrated mild to severe deficits regarding attention, concentration, memory and judgement in 81 % of players, which they conclude may indicate some degree of permanent organic brain damage, probably a cumulative result of repeated traumas from heading the ball. Since Tysvaer's studies are retrospective, however, their results must be viewed with caution, as the pattern of deficits noted are also consistent with alcohol-related brain impairment, which was not considered as a variable in their studies (N.H.M.R.C., 1993).

A study by Thomassen, Juul-Jensen, Olivarius, Braemer, and Christensen (1979) found nonsignificant differences between the performances of a group of 53 amateur boxers and a control group of 53 amateur soccer players on neuropsychological, neurological and EEG examinations. On the other hand, a series of studies conducted in Scandinavia (Haglund & Bergstrand, 1990; Haglund, Edman, Murelius, Oreland, and Sachs, 1990; and Haglund & Persson, 1990) aimed specifically at investigating the effects of boxing on the cranial matter used soccer players as a reference group on different measures of brain dysfunction. On these measures, soccer players showed markedly less significant brain dysfunction than their boxing counterparts, but some evidence of dysfunction was noted.

Jordan, Green, Galanty, Mandelbaum and Jabour (1996) suggest that the possible cause of encephalopathies in older players is the different nature of the ball. The older ball was made of leather, and tended to become waterlogged with an increase of up to 20% in weight when wet, whereas the modern balls are water-resistant and do not become heavier in wet and muddy conditions (ibid.). This may account for the findings of the retrospective studies, whose subjects would have been exposed to the older balls and conditions and may also have been less aware of the need to take adequate precautions against injury when heading the ball.

2.7.4. Studies on current players

Jordan, Green, Galanty, Mandelbaum and Jabour (1996) used magnetic resonance imaging (MRI) and a questionnaire on head injury symptoms on a sample of 20 US national soccer team players to investigate acute and chronic brain injury in soccer. They used a control group of 25 track athletes. They report that soccer is classified as a contact or collision sport by the American Academy of Paediatrics. Their study concludes that "evidence of encephalopathy in soccer players relates more to acute head injury received playing soccer than from repetitive heading." They also conclude that "soccer exposes the player to a substantial risk of acute head injury but not cumulative brain injury related to repetitive contact with a soccer ball" (Jordan et al., 1996). A possible difficulty in this study is that the subjects involved belong to an elite group of soccer players, and no consideration was given in their conclusion to other, possibly less skilled soccer players who may not have received the same degree of training in correct heading techniques.

Abreau, Templer, Schuyler and Hutchison (1990) found evidence of significantly greater incidence (based on self-report) of post-concussive symptoms in soccer players than in a control group of tennis players.

2.7.5. How may a head injury occur in soccer?

Heading the ball alone may not be the only way in which a soccer player places himself a risk of sustaining head injuries. Injuries to other limbs may cause a player to alter his heading technique in order to avoid further injury to the injured part (Fridjohn, personal communication to the writer, 1994). Such modifications to heading technique may prove to be harmful.

Although acute head injuries are rare in soccer, probable causes of brain injury on the field have been identified as the following (N.H.M.R.C., 1993):

1) The cumulative effect of the player's head colliding with the ball.

2) High speed collisions between the player and other players, or between the player and the goal posts.

3) Rotational injury caused by faulty heading technique.

4). The player's head striking the ground following a tackle (whether a legal tackle or involving foul play).

This is partly echoed by Jordan et al. (1996) where they contend that playing soccer has the potential for head injury in two distinct ways. These are that injury may occur through major impact with another object (e.g. foot, head, elbow, ground or goal post) that causes an acute injury; or that injury may occur through chronic injury due to repetitive, minor head impacts with the ball that may lead to cumulative encephalopathy (Jordan et al., 1996.) They do not elaborate on a potential for higher risk of the latter owing to incorrect heading technique and the possible concomitant rotational injuries.

Most fatalities in soccer are related to player impact with the goal post (Janda, Bir, Wild, Olson and Hensinger, 1995), and head and facial injuries have been found to account for 11.3% of soccer injuries. They investigated padding the goal posts to reduce injuries, and found that horizontal impact was reduced by 31% and vertical impact was reduced by 63%. No adverse effects were found in reference to the rebound of the ball off the padded post (as reported by referees), and spectators who had not been informed of the padding were not even aware that it was there (Janda et al., 1995). These findings are important and would constitute a viable method of injury reduction in soccer.

Witol and Webbe (1994) investigated the presence of neuropsychological deficits associated with differing exposure to heading, which they conceptualise as "repeated subconcussive blows to the head". While much of their battery measured verbal abilities, they found that 40% of the "high-heading" group (frequent headers of the ball) received impaired scores specifically on the Trail-Making Test, which is a visual sequencing task with a psychomotor component, and that a substantial proportion of soccer players showed deficits on other neuropsycholo, al tests. They conclude that, "the presence of consistent main effects due to heading, and the high levels of clinical impairment suggest that the practice of heading the ball in soccer needs to be re-examined in light of potentially permanent impairment in brain function," (Witol and Webbe, 1994). It must be noted that Witol and Webbe had a comparatively small sample (N= 60), as well as no control group, and their conclusions may therefore need to be viewed with caution.

Shuttleworth-Jordan et al. (1993) point out with regard to rugby that motor dexterity is intrinsic to performance in the sport itself, and impairment in this area may predispose players to further injury. It is argued that this also applies to soccer.

2.7.6 Children's soccer

Tysvaer and Storli (1989) noted that younger soccer players who had less experience of heading the ball showed greater EEG changes, leading them to conclude that proper technique is important to injury prevention. However, they acknowledge that the high incidence of EEG changes may also be due to the young players' higher susceptibility to trauma. A greater incidence of acute head injuries is reported among children, which may be explained by their lack of experience and the increased ratio of ball weight to their head weight (Tysvaer and Storli, 1989).

The game of soccer as played by children would not appear to expose its participants to injuries as serious as those likely to be sustained by adults, in that it is not played at comparable speeds, and the level of commitment displayed by the younger participants is not generally as high as that seen in adults, although Tysvaer and Storli (1989) would appear to suggest otherwise.

These factors were observed during the course of matches and practices by the present writer. Curiously, it seemed that more commitment to heading the ball was shown in practices, when competing with team-mates, than during matches, when competing with opponents. Players in the age group of this study were observed by the researcher to avoid heading the ball as much as possible, preferring to let an aerial ball bounce and try to control it with the chest or foot. Players who headed the ball frequently were remarked upon as being unusual compared to the others by casual observers, who did not comprise coaches or people with any expertise in soccer techniques.

Precautions are taken in Australia (N.H.M.R.C., 1993) to modify the rules of the game in junior level soccer in order to minimise injury. These include using smaller, lighter footballs and slightly under-inflated balls to minimise trauma to the head and neck. This suggests that during childhood soccer, relatively minor injuries could be sustained which form the beginnings of later deficits that may only manifest in adulthood, and may seem unrelated to what happened on the field of play many years before.

2.7.7 Who is at risk?

At this point a consideration of the four types of soccer playing positions is necessary.

The goalkeeper is the primary defensive player, and the only player in the team who is allowed to use his hands, provided he is in the 18-yard area at the time. As such he is unlikely to head the ball with any great frequency unless he finds himself outside his area, in which case he may not touch the ball with his hands. The position of goalkeeper has inherent dangers, in that the player is sometimes required to place his body at risk in attempting to prevent the opposition from scoring a goal. He will sometimes throw his body in front of oncoming players in order to claim the ball, and would also be particularly at risk of colliding with the goal-posts. The goalkeeper may also be required to jump into the air to catc[illegible] ball and would run the risk of a collision with another player while in the air. Referees tend to be especially protective of goalkeepers and tend to penalise infringements on the goalkeeper that may not be penalised if perpetrated on another player.

Tysvaer and Storli (1989) excluded goalkeepers from their sample, but it is suggested that it is dangerous to exclude any position from a study investigating head injury in soccer players. Dailey and Barsan (1992) consider goalkeepers to be at risk of head injury although they are permitted to use their hands rather than their heads to field shots on goal. They recommend that goalkeepers be allowed to wear helmets since goalkeepers are at risk of head injury from other players' boots or knees when they go to ground to field the ball. Daily and Barsan (1992) do not recommend that other players adopt protective headgear since this would change the character of the game. Since goalkeepers are at great risk of colliding with the goal post, they have actually been found to account for 18% of all soccer injuries (Janda et al., 1995) despite making up only 6% of the total soccer playing population.

Defensive players are often required to head the ball since many teams favour the "long-ball" approach to attacking in soccer, i.e. they tend to kick the ball as high and as far as they can in the direction of the opposition's goal hoping that the opposition defenders make an error in judgement and miss the header, thereby allowing their own teams' forwards to capitalise. Mostly defensive players tend to be selected on a good ability to head the ball as well as to tackle well. A defender may therefore be at risk of the more cumulative effects of heading. Since defenders often have to challenge other players for the aerial ball, they too are at risk of high-speed collisions. A defender would usually be expected to have to head the ball in a straight line (with translational acceleration). Illegal tackles (fouls) on defenders are less common than on other positions, although they are seen and may result in severe injuries.

The midfield players tend to be the creative players on the field. They tend to have a high work rate on the field, meaning that they cover a lot of ground in assisting both the forwards on attack and the defenders in defence. They would also be required to make many tackles, although this would perhaps not be as much a part of their job description as of a defender's. The midfielder may head the ball on many occasions during a match, and since they are creative, they run the risk of being tackled illegally, which may result in a hard collision with the ground. High-speed collisions are also a probability with this position. A midfield player may also modify his learned heading technique in order to create an opportunity to score a goal, which may result in rotational injuries.

Attacking players, or forwards, also tend to be creative players, and as such run the risk of sustaining injuries from illegal tackles. Since their primary requirement on the field is to attempt to score goals, they too may modify heading techniques and run the risk of sustaining rotational injuries as they may utilise rapid sideways flicking motions of the head in order to direct the ball toward the goal. High speed collisions, particularly with the goalkeeper and defenders, are a possible risk on the field.

Any player on the field may be hit on the head inadvertently by a fast-moving ball, and this is a risk that would be impossible to eliminate.

2.8 Conclusions

The evidence accumulated is controversial and contradictory, although it appears that there is enough evidence of potentially problematic head injuries in soccer to justify concern regarding the game. Taking all the evidence into consideration, it can be seen that there is inconclusive evidence that soccer players are at greater risk of sustaining disruptions of neuropsychological functioning than non-sporting controls, but when their performance on measures of neuropsychological functioning is compared to participants in more violent sports, no significant discrepancies have been reported. Details of damage to the brain and how it occurred have not been determined. Few studies thus far have attempted to identify likely causes of injury on the field of play, nor players most likely to sustain head injury. For this reason, the present study aims not only to investigate the incidence of neuropsychological impairment, but to investigate the possible causes of head injury and positions most at risk.

CHAPTER 3.

RESEARCH METHODOLOGY

3.1 AIMS OF THE STUDY

The study aims to investigate the incidence and severity of neuropsychological dysfunction in soccer players by comparing the performances of two groups of soccer players and a group of equivalent controls on a battery of neuropsychological tests.

The object of the study is to look for improved performance on the battery of neuropsychological tests as a result of a practice effect. If no such improvement is noted, it may be postulated that soccer players are sustaining subtle disruptions of neuropsychological functioning affecting their learning ability.

No alternate forms of any of the tests were used and therefore the subjects would be expected to show practice effects following repeated exposure to the same test material. Other reasons for expecting an improvement in speed on subsequent administrations of the test battery comprise maturational effects in that the subjects will have aged chronologically between administrations. However, this study expected to find evidence of a reduction in practice effects, particularly in the subjects who are exposed to most soccer play. The lack of an improvement, or even a regression in performance following repeated exposure to the test material may be seen to be indicative of the possibility of subtle neuropsychological or cognitive dysfunction resulting from exposure to soccer play.

3.2. HYPOTHESES

1) Children who have played soccer over the course of a soccer season will display reduced learning effects compared to those who have not.

2) Children who have been exposed to more soccer play will perform more poorly or slower than those who have been exposed to less soccer play.

3) Deficits in performance are not the result of one or more identifiable concussive (heading) injury sustained on the field of play.

3.3 RESEARCH QUESTIONS

1) Is there evidence of disruption in neuropsychological functioning over the course of a soccer season?

2) Was this disruption sustained following an injury to the head?

3) Do soccer players show reduced practice effects on neuropsychological tests compared to their controls?

4) Do school soccer players (who would play less frequently than their club counterparts and may not have been exposed to comparable levels of coaching) show reduced practice effects on neuropsychological tests compared to club soccer players?

3.4 SUBJECTS

Children were selected as the subjects of this study in order to minimise the possibility of extraneous variables interfering with the results, as may be found in an adult sample. With adult subjects, the possibility exists of such factors as: disparities in education levels, head injuries previously sustained (especially in childhood) of which the subject may be unaware; and language barriers. Children may be considered better subjects as parents would have access to the child's medical records and be able to confirm head injuries sustained previously.

The sample used in this study was derived from 3 primary schools, namely St David's and St Peter's Preparatory schools and Bryandale Primary School, as well as 2 football clubs, Wits University and Mark's Parkhurst, both based in Emmarentia. The subjects were all in the under-11 age group, i.e. born in 1984-1985 (Mean age 10.6 years, *S.D.* 2.76 months, at initial assessment). Players at club level were chosen as a high-frequency soccer-playing group, while the school players were chosen as a comparison group of lower-frequency soccer players.

Permission to conduct assessment on the experimental subjects was obtained from the clubs and schools involved, as well as from each prospective testee's parents. The latter was done by means of a permission slip sent home with each team member at the first practice of the soccer season, and testing commenced within two weeks of that date. Since most early season training would be devoted to fitness training, it is unlikely that the time needed to obtain the responses parents would adversely influence performance on the tests. Most parents were very co-operative, particularly at the end of the season when some testing had to take place at the subjects' homes.

Permission to conduct assessments was also obtained from the parents of the control subjects in this manner. They too were very co-operative. Controls included pupils of Bryandale Primary school as well as other privately seen individuals (i.e. independently of that school), who do not participate in soccer.

Players of all soccer positions have been included in this study. The sample of school players excluded players who played for a club in addition to playing at school. The sample of school players comprised 28 boys. The school players were largely derived from the higher-skilled teams in their age group, which suggests that their skill levels approximate those of the club players. Each subject was questioned before assessment as to whether they had sustained a concussion within the last five years, and those that indicated that they had sustained concussion were to be excluded from the sample. None of the school players was excluded on this basis.

The soccer players who played for club teams play soccer both at school and at their clubs and would therefore played more often, both at practices and at games, thus increasing their chances of sustaining injuries. The sample of club players comprised 24 boys. This group was also questioned as to any prior history of concussion, with the same exclusion considerations as the school players. No boys were excluded from this sample for these reasons.

In addition to the experimental groups, a group of 21 equivalent controls was tested. These were selected according to age and gender, and were persons with minimal experience of playing soccer. In addition, the controls were screened in terms of not having sustained concussion previously, and not having been involved in activities in which there exists a risk of sustaining an injury to the head, such as equestrian and motor sports.

Subjects who have had repeated neuropsychological tests administered to them should register improved performance on the tests as a result of practice effects, or repeated exposure to the same material. If such improved performance were not seen in the soccer playing subjects, in the absence of an identified concussive injury, it may be postulated that this lack of a practice effect occurs as a result of possible neuropsychological dysfunction. It is conjectured that this results from cumulative blows to the head.

Six of the subjects were lost to the sample owing to emigration. In all these cases, the subjects emigrated after the initial testing, but before mid-season tests could be administered. Their results were consequently not used in this study.

3.5. TEST MATERIALS

Brain trauma generally spares verbal IQ relative to performance IQ (Parker and Rosenblum, 1996) and "hold" as opposed to "non-hold" sub-tests of intelligence scales. For this reason, non-verbal tests were used in composing the battery of tests used in this study. Another difficulty that was eliminated by using non-verbal tests was the difficulty inherent in testing people of diverse preferred first languages, as are found in South Africa. The battery of tests was also composed to comprise tests that were considered to afford the best opportunity to investigate the incidence of practice effects. Shuttleworth-Jordan et al. (1993) administered a similar battery of tests on a group of adult rugby players.

The testing procedures had to be designed to fit in with the sport practices and to ensure the co-operation of the coaches. As a result, time constraints were a significant rationale behind using only selected items of longer tests, such as the items from the Block Design sub-test of the Wechsler Intelligence Scale for Children (Revised), as well as only the first four items of the

Clinical Neuropsychological Evaluation Instrument (Majovski, Tanguay, Russell, Sigman, Crumley and Goldenberg, 1979).

The individual tests within this battery of neuropsychological tests were delineated as highly speeded or moderately speeded test following the example of Bawden, Knights and Winogron (1985). This study classified neuropsychological tests into three categories according to the degree of speed required for successful performance. For example, tests placed in the low speed category (which do not form part of this battery) require that subjects perform slowly in order to do well, or are those for which speed is an unimportant factor for successful performance. The Bawden, Knights and Winogron (1985) study found that severely head injured children performed very poorly on highly speeded tests compared to moderately speeded tests, while children with mild head injury performed at roughly the same level on both kinds of speeded test.

While the highly speeded tests are psychomotor in nature, they do not require as much cognitive processing as the moderately speeded tests. The battery of tests administered on the subjects consists of the following tests:

3.5.1. HIGHLY SPEEDED TESTS

1) The Denckla Finger-tapping Test: a test in which the subject is required to tap the index finger and thumb together of each hand 21 times as rapidly as possible. This test measures manual (psychomotor) speed and fine-motor control. Norms have been established for children and adults on this test. Finger-tapping tests have been used extensively by neuropsychologists in studies of head injuries in children, (Bawden, Knights and Winogron, 1985; Gulbrandsen, 1984).

2) The Annett's Peg Moving Task. A test in which ten pegs are transferred from holes on one side of a pegboard with the ipsilateral hand to holes on the contralateral side. The pegboard consists of two parallel rows of ten holes 1.27 cm in diameter and 2.54 cm apart, the rows being 20.32 cm apart, and 10 doweling pegs 5.08 cm long by 0.95 cm wide (Annett, 1992b). This test measures manual dexterity and speed, as well as visuomotor co-ordination. Norms have been generated for adults and children on this test.

3) Selected items from the Clinical Neuropsychological Evaluation Instrument (Majovski, Tanguay, Russell, Sigman, Crumley and Goldenberg, 1979) in order to evaluate motor functions (simple movement and dynamic organisation). This test was designed specifically for use with children and adolescents. Only the first four items of the test were used in this battery, since there was a need for brevity in testing time to avoid conflict with the coaches. Furthermore, the other items of the test relied more on verbal comprehension, which raised the possibility of language bias.

3.5.2. MODERATELY SPEEDED TESTS.

1) The Trail-Making Test (Parts A and B): A test in which the subject must connect circles containing numbers in numerical order (Part A), and Part B in which circles, some of which contain numbers and others of which contain letters, must be connected in combined numerical and alphabetical order (1-A-2-B, etc.). This test provides a measure of divided attention (van Zomeren and Brouwer, 1992), flexibility and speed, and it requires sequential problem-solving abilities. It is also a test of information processing and working memory, and is sensitive to diffuse brain damage effects. The test is supposed to measure functions such as ability to

perceive a double relationship, to plan, and to "shift" (Tysvaer and Løchen, 1991) and a good performance on this test requires power of concentration, alertness and attention to the task. The test is a complex test that subsumes aspects of both abstraction and visual scanning or attention (O'Donnell, MacGregor, Dabrowski, Oestreicher and Romero, 1994).

Because of its brevity and simplicity of administration, the Trail-Making Test has been extremely popular both as a screening and as a diagnostic test of cognitive impairment (Vickers, Vincent and Medvedev, 1996). The two parts of the Trail-Making Test may be differentially sensitive to impairment in the left and right cerebral hemispheres (ibid.), and trail-making performance is considered to be a sensitive test of cognitive impairment not because it measures an important *part* of what the brain does, but because it effectively involves *most* (perhaps *all*) of the important kinds of function that the brain performs (Vickers, Vincent and Medvedev, 1996 - their emphasis). Franzen, Paul and Iverson (1996) point out that the Trail-making test is sometimes employed serially to evaluate cognitively impaired patients, but that the serial application of the Trail-Making Test is problematic because of the existence of practice effects. The Trail-Making Test shares this characteristic with other neuropsychological assessment instruments.

This test has been used extensively in neuropsychological assessment of children and of sports participants (Barth et al., 1989; Gulbrandsen, 1984; Martini et al., 1990; Witol and Webbe, 1994). Tysvaer and Løchen (1991) used specifically this test in their retrospective study and particularly significant differences ($p < 0.01$) between the soccer players in their sample and controls were found using the Man-Whitney U test. Apart from its use as a speeded visuomotor test, it has been reported that patients with frontal (particularly basomedial) lesions have difficulty with the flexible control of inhibition needed for the task, and are differentially slower on Part B (Walsh, 1985).

2) Selected designs (1,3,6 and 9) from the Block Design task of the Wechsler Intelligence Scale for Children (Revised). This test was used to provide a measure of non-verbal reasoning, but is also a test in which the subject's performance is timed, and thus would provide a measure of manual dexterity and speed. This test also measures the analysis and synthesis of visual-spatial information. The Block design sub-test has also been widely used in the assessment of children with head injury (Bawden et al., 1985; Gulbrandsen, 1984; Martini, Beers and Ryan, 1990; Rutter, Chadwick, Shaffer and Brown, 1980).

The reason for abbreviating this test lay in the aforementioned time constraints imposed on the testing session. The designs were deliberately chosen to comprise 50% non-embedded items (1 and 3) and 50% embedded items (6 and 9). In addition, item 9 was selected as a more complex task in that more blocks are needed to reproduce the design. An embedded item is one where the elements of the item are not immediately obvious perceptually. Thus these items [...] prove differentially difficult for those with analytical or problem-solving disorders (Walsh, 1985, p15).

To date, South African norms are not available for all of these tests, but since most of the tests are non-verbal and do not require complex linguistic processing, the American norms can be applied meaningfully to South African subjects. Apart from this, it facilitates the application of a pass/fail approach and time scales.

3.5.3. QUESTIONNAIRES

In addition to the aforementioned tests, the initial testing utilised an adaptation of the Annett's Handedness Questionnaire (1970 - cf. Appendix 2) in order to establish lateralisation of functioning. Laterality has been associated with "cerebral dominance", which may be described (Annett, 1992a) as the "cerebral hemisphere with main responsibility for speech", or language processing (Cimino, 1994) and is therefore important to note the laterality of the subjects. Handedness will also influence the interpretation of data from motor tasks (Cimino, 1994).

Segalowitz and Brown (1991) have established that there is a relationship between mixed handedness and head injury, in that there is an increased likelihood of head injury with mixed handedness, as opposed to either left- or right-handedness. Annett (1992a) presents the problem that since sinistrality is not a salient characteristic for most right-handers, it seems likely that left-handedness will be under-reported, and therefore people who tend toward mixed-handedness may be misclassified as right-handers.

Two other self-administered questionnaires were to have been given to the subjects who sustained injuries in which concussion was present: the Post-concussion Checklist or PCL (Oddy, Humphrey and Uttley, 1978-cf. Appendix 4) and the Post-concussion Syndrome Checklist or PCSC (Gouvier, Cubic, Jones, Brantley and Cutlip, 1992-cf. Appendix 3). Appended to the former was a brief section aimed at ascertaining exactly how the injury was sustained, with a space left for the subject to fill in any alternative not provided.

3.6. PROCEDURE

The subjects were tested on the aforementioned battery of tests three times over the course of one season, taking into account the average number of games played per player). All of the subjects were tested at the beginning of the season, at a point approximately halfway through the season, i.e. at approximately 3 months after the initial assessment, and again at the conclusion thereof, i.e. at approximately 6 months. The reason for the mid-season testing was to obtain a gauge of practice effect over the course of a period of time, in order to avoid the potential for an extraneous variable (such as emotional trauma) interfering with the results of the retest.

Each subject who sustained an injury on the field that involved concussion was to have been retested, using the same battery, as close as possible to 24 hours after sustaining the injury, then again within 72 hours after the injury and finally ten days following the injury, to monitor recovery from the injury. As it happened, none of the players in the sample incurred such an injury.

Players who sustained other injuries were also to have been noted and monitored, as they run the risk of both head injuries, and of injuries that affect the speed with which they are able to perform the tasks. To this end, coaches were requested to note which, if any, player sustained an injury, and to note how the injury was sustained. None of the players in this sample was reported to have sustained injuries.

The controls were likewise tested at points approximating those of the players. If they were to have sustained injuries of whatever nature, they were also required to notify the writer, in terms of the rationale given previously.

Two research assistants assisted in the administration of the tests. Each is a registered psychometrist, and each was briefed to administer the test instructions verbatim to the subjects in order to avoid interviewer bias, and to ensure reliability.

Testing took approximately fifteen minutes to complete per subject. This time decreased slightly during the later assessments.

Problems encountered during the testing were minimal. It was found necessary to test as far from the practice fields as possible, in order to minimise distraction for the players. The subjects were generally co-operative, and interested in the tests. The parents of the subjects also expressed interest in the study, and were very accommodating when circumstances dictated conducting testing at their homes. The coaches were co-operative and fairly enthusiastic about the study. In order to minimise the time taken to complete testing at the various stages of the season, it was found necessary to have two testers and two copies of the test material, since the coaches expressed reservation about the number of players they would spare from practices.

Future studies may find it useful to ensure that as many matches and practices as possible are attended in order to monitor subjects for possible injuries that the coaches or trainers may consider unimportant.

CHAPTER 4

RESULTS

This research employed a pretest-posttest research design with an equivalent control group. Using the SAS statistical package, analysis of variance was used to make pre-season, mid-season and post-season comparisons between performances of the soccer playing and control groups, and between the school and club players. Analysis of variance also differentiated among playing positions, as well as dominant hand, eye and foot. Post-hoc analysis of variance was used to determine whether improvements or regressions over time discriminated players from controls, as well as to determine whether there was any significant difference between players and controls at a given stage (pre-season, mid-season or post-season). Analysis of covariance was used to investigate the relationship between player/control and the time of season when the tests were administered.

The club players played approximately three times as many games as the school players (means of 25 and 9 games respectively) and would have played soccer at practices and games approximately 2½ times more frequently than the school players. This would suggest that the club players are more at risk of sustaining mild head injuries or other demonstrable neuropsychological deficits.

HIGHLY SPEEDED TESTS.

Finger Tapping

Tables 1 and 2 provide the means and standard deviations for the two administrations, as well as the *F*-values calculated for main effects over the course of the season.

TABLE 1. Finger-tapping (right-hand administration)

* NOTE *: In all the following tables, the MEAN score refers to time in seconds.

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		F-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	2.51 n.s.
PRE-SEASON	5.39	1.25	5.05	0.96	5.50	1.01	
MID-SEASON	5.08	1.23	4.92	1.02	5.22	0.99	
POST-SEASON	4.46	0.68	5.13	1.55	5.02	0.91	

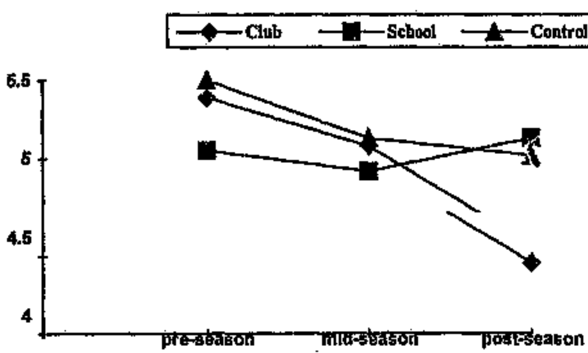

Figure 1. Finger tapping (Right Hand)

Right-hand administration: No significant overall main effect was found for time, and no significant difference was found between players and controls, nor among the distribution of positions. However, the club players demonstrated a significant improvement over time (F = 4.26, $p < 0.02$), which was significant in pre-season/post-season comparisons.

On this right-hand administration, the goalkeepers demonstrated a significant improvement over time, both on pre-season/mid-season and on pre-season/post-season comparisons (F = 10.58, $p <$ 0.01). These results may need to be viewed with caution, since goalkeepers comprised only three subjects in this sample. Otherwise, no position as a whole demonstrated a significant increase in speed. While no overall effect was found for midfielders, the club midfielders showed a significant increase in speed ($F = 4.41$, $p < 0.03$), but only in pre-season/post-season comparisons.

Post-hoc analysis of variance reveals no significant difference between players and controls at any stage during the testing (pre-season to post-season). ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 21.70$, $p < 0.0001$), while no significant effect was found for players vs. controls.

TABLE 2. Finger-tapping (left-hand administration)

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		*F*-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	4.79 **
PRE-SEASON	5.72	1.27	5.47	1.05	5.58	1.18	
MID-SEASON	5.33	0.98	5.36	0.95	5.37	1.12	
POST-SEASON	4.80	0.66	5.13	0.93	5.18	1.02	

** $p < 0.009$

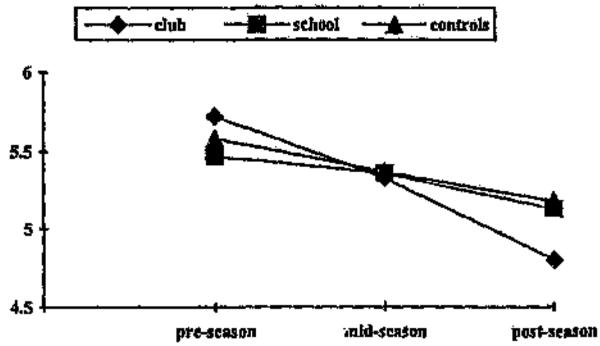

Figure 2. Finger-tapping (left hand)

Left-hand administration: A significant overall main effect was found for time ($F =$ [illegible], $p <$ 0.009), though only in pre-season/post-season comparisons, while no significant difference was found between players and controls, nor among the distribution of positions. Again it was only the club players who demonstrated a significant improvement over time ($F = 4.55$, $p < 0.02$), which was significant in pre-season/post-season comparisons.

On the left-hand administration, the midfield players as a whole constituted the only group that showed a significant increase in speed over time ($F = 4.05$, $p < 0.03$) in pre-season/post-season comparison, although on closer analysis, it was again only the club midfielders that showed a significant increase in speed over time ($F = 5.68$, $p < 0.01$).

Post-hoc ANOVA revealed no significant difference between players and controls at any stage during the testing (pre-season to post-season). ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 21.70$, $p < 0.0001$), while no significant effect was found for players vs. controls.

Clinical Neuropsychological Evaluation Instrument (Majovski et al., 1979)

Item 1

In item 1 of the C.N.E.I., the subject is required to touch each finger in turn with the thumb of the same hand. This is repeated 20 times for each hand in turn, and then with both hands together. Tables 3, 4 and 5 provide the means and standard deviations for the three administrations of this test.

TABLE 3. C.N.E.I. Item 1 (right-hand administration)

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		F-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	12.57 ****
PRE-SEASON	38.83	12.28	39.19	9.13	38.72	8.03	
MID-SEASON	33.03	6.05	34.38	4.18	33.95	6.16	
POST-SEASON	30.97	6.57	31.86	4.47	35.18	8.96	

**** $p < 0.0001$

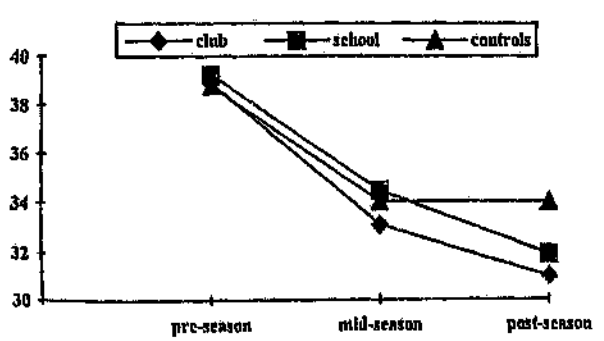

Figure 3. C.N.E.I. Item 1 - Right-hand

Right-hand administration: A significant overall main effect was found for time ($F = 12.57, p < 0.0001$), which was found in pre-season/mid-season and pre-season/post-season comparisons. Position was found to have a significant main effect ($F = 2.78, p < 0.03$), with midfielders performing significantly more slowly than defenders ($p < 0.05$), while no significant difference was found between players and controls.

Both the club ($F = 4.21, p < 0.02$) and school ($F = 7.89, p < 0.0009$) players demonstrated a significant improvement over time, which was significant in pre-season/post-season comparisons. Among the positions, it is noteworthy that both midfielders ($F = 4.15, p < 0.02$) and defenders ($F = 3.82, p < 0.04$) demonstrated significant improvements over time, although the earlier result indicates the latter to have performed significantly slower than the former. Closer analysis reveals that the club defenders ($F = 5.16, p < 0.02$), school forwards ($F = 6.55, p < 0.01$) and school midfielders ($F = 4.26, p < 0.03$) showed a significant improvement in speed over time on this administration.

Post-hoc ANOVA revealed no significant difference between players and controls at any stage during the testing (pre-season to post-season), although the post-season results approached significance. ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 9.40, p < 0.004$), while no significant effect was found for players vs. controls.

TABLE 4. C.N.E.I. Item 1 (left-hand administration)

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		F-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	13.70 ****
PRE-SEASON	39.61	11.41	40.24	10.07	40.92	6.89	
MID-SEASON	36.03	5.81	38.35	7.60	37.71	4.94	
POST-SEASON	32.06	4.71	34.07	4.16	35.35	5.37	

**** p < 0.0001

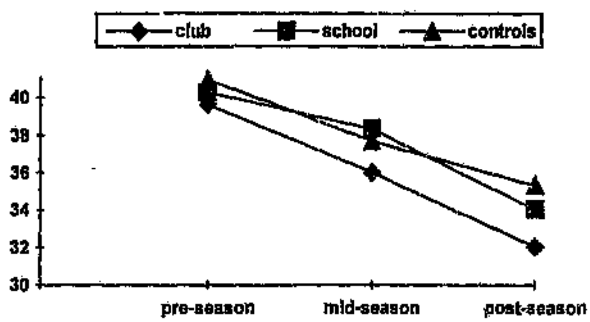

Figure 4. C.N.E.I. Item 1 - Left-hand.

Left-hand administration: A significant overall main effect was found for time ($F = 13.70$, $p < 0.0001$), which was found in pre-season/post-season and mid-season/post-season comparisons. No significant main effect was noted for positions, and no significant discrepancy was seen between players and controls.

On this administration, the controls ($F = 5.06$, $p < 0.01$), club ($F = 4.55$, $p < 0.01$), and school ($F = 4.32$, $p < 0.01$) players demonstrated a significant improvement over time. The midfield players as a whole ($F = 4.47$, $p < 0.02$) demonstrated a significant increase in speed over time (pre-season/post-season comparison), while closer analysis revealed that club defenders ($F =$

4.85, $p < 0.02$) and school forwards ($F = 4.11$, $p < 0.03$) showed a significant improvement in speed over time on this administration.

Post-hoc ANOVA revealed no significant difference between players and controls at any stage during the testing (pre-season to post-season), although the post-season results approached significance. ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 11.46$, $p < 0.002$), while no significant effect was found for players vs. controls.

TABLE 5. C.N.E.I. Item 1 (both-hands administration)

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		*F*-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	8.33 ****
PRE-SEASON	42.83	13.62	46.57	12.51	46.30	9.26	
MID-SEASON	39.68	8.76	44.26	7.88	43.08	6.80	
POST-SEASON	36.07	7.52	39.52	6.89	41.22	6.75	

**** p < 0.0003

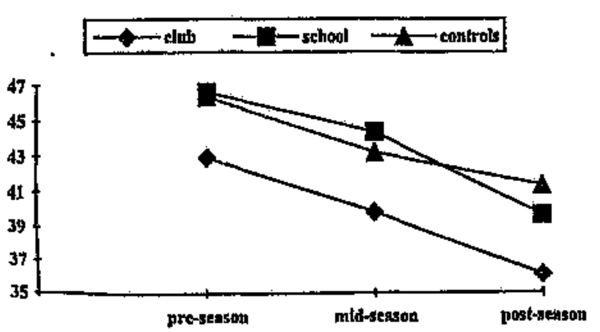

Figure 5. C.N.E.I. Item 1 - both hands.

Both-hands administration: A significant overall main effect was found for time ($F = 8.33$, $p < 0.0003$), which was found in pre-season/post-season comparisons. A significant main effect ($F = 5.07$, $p < 0.004$) was noted for positions, with midfielders performing significantly slower than both defenders and forward player ($p < 0.05$) and no significant discrepancy was seen between players and controls.

The only group to show a significant improvement over time was the school players ($F = 3.51$, $p < 0.04$). None of the positions demonstrated practice effects, nor did the breakdown of positions by club or school.

Post-hoc ANOVA revealed no significant difference between players and controls at any stage during the testing (pre-season to post-season), although the post-season results approached significance. ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 33.35$, $p < 0.0001$), while no significant effect was found for players vs. controls.

The controls were the only subjects on the C.N.E.I. item 1 who showed a significant improvement over time in terms of performance quality ($F = 8.42$, $p < 0.001$), which was rated on a scale from 0 = no disco-ordination to 2 = greater disco-ordination. This was true for both pre-season/mid-season and pre-season/post-season comparisons. This is more likely to be indicative of a poorer quality first performance (pre-season testing) on the part of the controls than a lack of improvement by the players.

Item 2

In item 2 of the C.N.E.I., the subject is required to place hands palm down on the table, and then alternatively spread and converge the fingers. This is done 20 times. Table 6 provides the means and standard deviations from this item.

TABLE 6. C.N.E.I. Item 2

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		*F*-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	9.35 ****
PRE-SEASON	20.07	7.58	18.72	5.26	16.93	6.30	
MID-SEASON	17.51	4.56	18.73	4.92	13.98	4.16	
POST-SEASON	15.72	5.06	15.12	3.30	13.49	4.18	

**** $p < 0.0001$

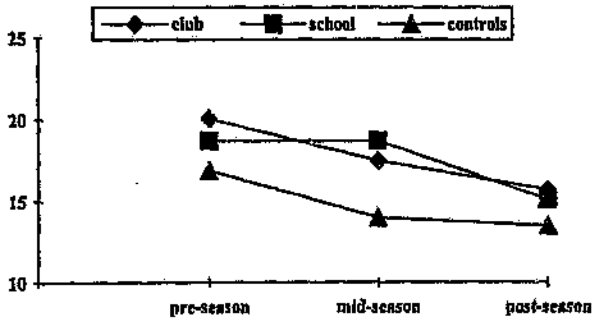

Figure 6. C.N.E.I. Item 2

A significant overall main effect was found for time ($F = 9.35$, $p < 0.0001$), which was found in pre-season/post-season comparisons. A significant main effect ($F = 3.85$, $p < 0.005$) was noted for positions, with midfielders performing significantly slower than controls, and a significant discrepancy was seen between players and controls ($p < 0.05$), with controls significantly faster than both school and club players. No significant discrepancy was found between club and school players. The controls' improvement over time approached significance ($F = 2.99$, $p < 0.06$), while the school players demonstrated a significant improvement over time ($F = 4.99$, $p < 0.01$) in pre-season/post-season comparisons.

Among the positions, the midfielders as a whole demonstrated a significant increase in speed over time ($F = 3.68$, $p < 0.04$), which on closer analysis seemed to result from the club midfielders' performance, who demonstrated a significant improvement ($F = 4.31$, $p < 0.03$)

Post-hoc ANOVA revealed a significant difference between the school players and controls at the mid-season testing, in favour of the latter, although these results were not reflected at any other stage during the testing (pre-season to post-season). ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 59.74$, $p < 0.0001$), as well as a significant effect ($F = 11.70$, $p < 0.0001$) when school players and controls were contrasted.

The dominant hand was found to have a significant effect on speed, with left-handers performing slower than their right-handed counterparts ($p < 0.05$).

From the graph, it is interesting to note how the controls started faster than the experimental subjects, and performed quicker throughout the course of the season.

Item 3

Item 3 of the C.N.E.I. requires the subject to place one hand palm down on the table, with the other in a fist, and then alternate between left-hand clenched, right-hand flat, and left-hand flat, right-hand clenched. This is done 20 times. Table 7 provides the means and standard deviations from this item.

TABLE 7. C.N.E.I. Item 3

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		*F*-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	7.37 ***
PRE-SEASON	23.24	9.51	20.19	6.40	18.60	7.85	
MID-SEASON	18.72	6.29	19.59	5.05	15.13	5.42	
POST-SEASON	17.61	6.50	17.05	4.34	15.13	6.09	

*** $p < 0.0008$

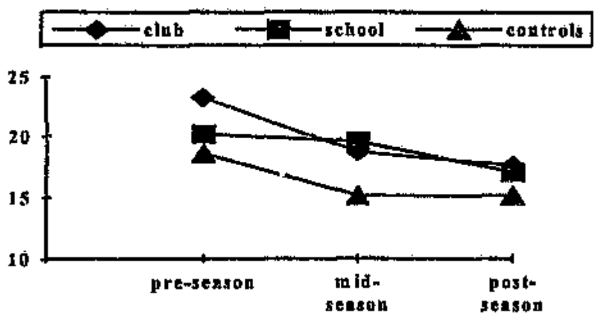

Figure 7. C.N.E.I. Item 3

A significant overall main effect was found for time ($F = 7.37$, $p < 0.0008$), which was found in pre-season/mid-season and pre-season/post-season comparisons. A significant main effect ($F = 3.51$, $p < 0.01$) was noted for positions, with midfielders and goalkeepers performing significantly slower than controls, and a significant discrepancy was seen between club players and controls ($p < 0.05$), with controls performing significantly faster. No significant discrepancy was found in the overall performance of the three groups of subjects.

None of the groups of subjects (players vs. controls) demonstrated a significant improvement in speed over time. The midfield players demonstrated a significant increase in speed over time ($F = 3.87$, $p < 0.03$), although on more detailed analysis, the club midfielders were the only subgroup found to show a significant improvement over time ($F = 4.02$, $p < 0.04$).

Post-hoc ANOVA revealed no significant difference between players and controls at any stage during the testing (pre-season to post-season). ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 21.25$, $p < 0.0001$), while no significant effect was found for players vs. controls.

Item 4

Item 4 of the Clinical Neuropsychological Evaluation Instrument: Subject is required to place both hands on the table, and alternate fist with knuckles flat, then fist on edge, then palm down. Subject does this 20 times. Table 8 provides the means and standard deviations from this item.

TABLE 8. C.N.E.I. Item 4

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		F-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	18.28 ****
PRE-SEASON	35.32	8.86	34.25	6.40	33.70	10.11	
MID-SEASON	26.70	6.45	28.63	4.71	29.33	8.45	
POST-SEASON	26.81	7.12	27.11	3.78	28.37	7.43	

**** $p < 0.0001$

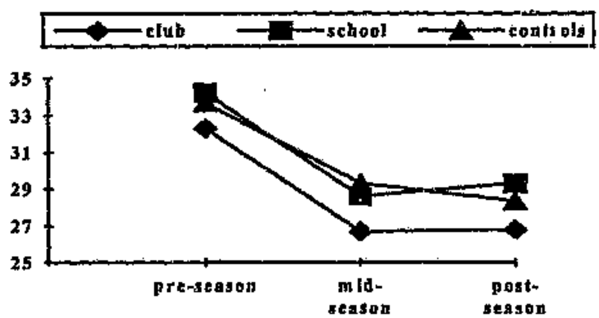

Figure 8. C.N.E.I. Item 4.

A significant overall main effect was found for time ($F = 18.28$, $p < 0.0001$), which was found in pre-season/mid-season and pre-season/post-season comparisons. No significant main effect was noted for positions, nor for players as opposed to controls.

The soccer playing subjects, both club ($F = 8.35$, $p < 0.0007$) and school ($F = 13.62$, $p < 0.0001$) players, demonstrated a significant improvement in speed over time, as did defenders as a whole ($F = 9.86$, $p < 0.0004$). This was most notable in the school defenders ($F = 10.18$, $p < 0.001$). Midfielders were also found to have improved in terms of speed ($F = 5.00$, $p < 0.01$), although this did not discriminate club from school midfielders.

Post-hoc ANOVA revealed no significant difference between players and controls at any stage during the testing (pre-season to post-season). ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 46.17$, $p < 0.0001$), while no significant effect was found for players vs. controls.

Annett's Pegmoving task

Table 9 provides the means and standard deviations from the right-hand administration of this item.

TABLE 9: Annett's Pegmoving task right-hand

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		*F*-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	6.87 ***
PRE-SEASON	12.63	1.89	11.62	1.22	12.28	1.73	
MID-SEASON	12.52	1.68	11.15	1.44	11.49	1.86	
POST-SEASON	11.29	1.52	11.04	1.13	11.13	1.71	

*** $p < 0.001$

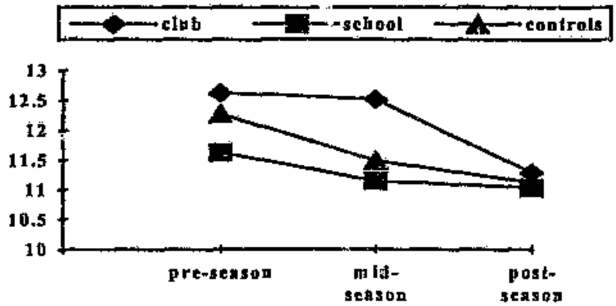

Figure 9: Pegmoving right-hand

Right-hand administration: A significant overall main effect was found for time ($F = 6.87$, $p < 0.001$), which was found in pre-season/post-season comparisons. No significant main effect was noted for positions, but a significant main effect ($F = 6.22$, $p < 0.02$) was found between the soccer playing groups, with school players performing significantly faster than their club counterparts.

The club players ($F = 3.85$, $p < 0.03$) demonstrated a significant improvement in speed over time, which may be accounted for by the club midfield players, who showed a significant improvement ($F = 4.95$, $p < 0.02$) from pre-season to post-season testing. Midfielders as a whole demonstrated a significant improvement over time ($F = 6.20$, $p < 0.005$), both in pre-season/post-season and mid-season/post-season comparisons.

Post-hoc ANOVA revealed no significant difference between players and controls at any stage during the testing (pre- n to post-season). ANCOVA using the mid-season test as the covariate and post-s st as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 31.32$, $p < 0.0001$), while no significant effect was found for players vs. controls.

Table 10 provides the means and standard deviations from the left-hand administration of this item.

TABLE 10. Annett's Pegmoving task left-hand

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		F-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	5.03 **
PRE-SEASON	13.58	1.63	12.32	1.36	12.35	1.73	
MID-SEASON	13.24	1.58	12.62	1.41	11.96	1.35	
POST-SEASON	12.19	1.71	12.09	1.43	11.57	1.34	

** p < 0.008

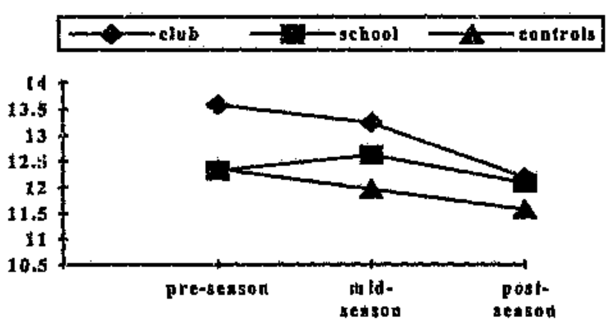

Figure 10. Pegmoving left-hand.

Left-hand administration: A significant overall main effect was found for time ($F = 5.03$, $p < 0.008$), which was found in pre-season/post-season comparisons. A significant main effect was noted for positions ($F = 6.22$, $p < 0.02$), with midfield players performing significantly slower than defenders, forwards and controls. A significant main effect ($F = 4.89$, $p < 0.03$) was also found for players vs. controls, with club players performing significantly slower than the school players and controls, although no significant discrepancy was found between school players and controls.

The club players ($F = 4.08$, $p < 0.02$) demonstrated a significant improvement in speed over time, though only in pre-season/post-season comparisons. Post-hoc ANOVA revealed a significant difference between club players and the other two groups in favour of the latter ($F = 4.93$, $p < 0.01$) at the pre-season stage of the testing, with a difference approaching significance, in favour of the controls, at the mid season stage. ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 26.41$, $p < 0.0001$), while no significant effect was found for players vs. co[illegible]ls.

MODERATELY SPEEDED TESTS

Trail-Making Test

Part A.

Table 11 provides the means and standard deviations from this item.

TABLE 11. Trail-Making Test Part A

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		F-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	6.13 ****
PRE-SEASON	39.95	12.31	39.59	13.41	38.53	9.59	
MID-SEASON	38.52	13.76	33.49	7.89	34.88	8.35	
POST-SEASON	32.73	8.81	33.75	7.94	33.74	7.54	

**** $p < 0.003$

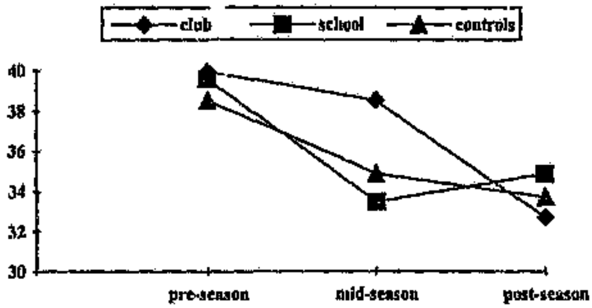

Figure 11. Trails Part A

A significant overall main effect was found for time ($F = 6.18$, $p < 0.003$), which was found in pre-season/post-season comparisons. No significant main effect was noted for positions, nor for players as opposed to controls.

Neither the controls nor the club nor school players as a group demonstrated a significant improvement over time. Post-hoc ANOVA revealed no significant difference between players and controls at any stage during the testing (pre-season to post-season). ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 66.58$, $p < 0.0001$), while no significant effect was found for players vs. controls.

The graph (figure 11) clearly shows a regression in performance from mid-season to post-season, albeit a slight improvement overall, for the school players, with a fairly dramatic improvement by the club players from mid-season to post-season testing.

Part B.

Table 12 provides the means and standard deviations from this item.

TABLE 12. Trail-Making Test Part B.

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		*F*-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	13.19 ****
PRE-SEASON	106.53	38.66	92.21	18.52	90.59	22.36	
MID-SEASON	80.65	25.84	75.07	15.53	85.33	19.56	
POST-SEASON	77.92	26.68	74.18	19.70	78.25	14.59	

**** $p < 0.0001$

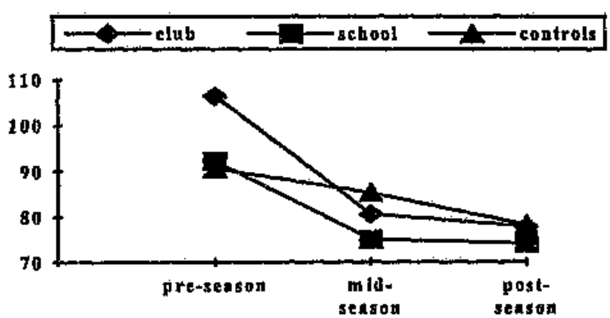

Figure 12. Trails Part B.

A significant overall main effect was found for time ($F = 13.19$, $p < 0.0001$), which was found in pre-season/mid-season and pre-season/post-season comparisons. No significant main effect was noted for positions, nor for players as opposed to controls.

Both the club ($F = 5.14$, $p < 0.009$) and school ($F = 7.20$, $p < 0.002$) players demonstrated a significant improvement over time, the former on pre-season/post-season comparisons, and the latter on both pre-season/mid-season and pre-season/post-season comparisons. Defenders demonstrated a significant improvement in speed over time ($F = 6.88$, $p < 0.003$), which was largely accounted for by the school defenders ($F = 5.50$, $p < 0.01$). Club midfielders also demonstrated an improvement over time ($F = 4.28$, $p < 0.03$)

Post-hoc ANOVA revealed no significant difference between players an

during the testing (pre-season to post-season). ANCOVA using the mid-se

covariate and post-season test as the dependent variable demonstrate that the pre-season score has a significant effect on the mid-season score ($F = 82.26$, $p < 0.0001$), while no significant effect was found for players vs. controls.

Block Design

Design 1.

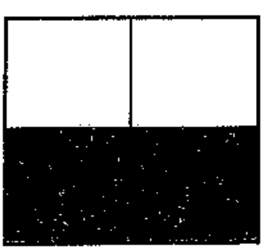

Figure 13. Block Design 1

In this design the subject must place two blocks with the white sides facing up above two blocks with the red sides facing up. This is considered a non-embedded design since guidelines are present in the design. Table 13 provides the means and standard deviations from this item, with the dependent variable being time taken to completion.

TABLE 13. Block Design Item 1

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		*F*-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	1.69 (N.S.)
PRE-SEASON	8.35	5.07	8.39	7.94	7.79	3.95	
MID-SEASON	9.03	5.52	9.43	4.19	6.90	2.64	
POST-SEASON	8.02	3.82	6.82	3.72	5.92	1.93	

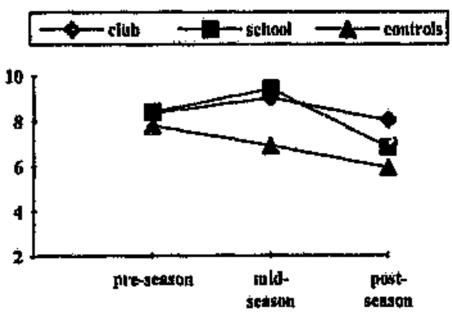

Figure 14 W.I.S.C.-R. Block Design 1

No significant overall main effect was found for time, nor for players as opposed to controls. A significant main effect was noted for positions ($F = 4.18$, $p < 0.003$), with midfielders performing significantly slower than both the controls and the defenders.

Neither the players nor controls demonstrated a significant increase in speed over time, which also held true for the distribution of players. Post-hoc ANOVA revealed no significant difference between players and controls at any stage during the testing (pre-season to post-season). ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable failed to demonstrate that the pre-season score has a significant effect on the mid-season score, and no significant effect was found for players vs. controls.

The graph suggests that club and school players actually regressed from first to second testing before improving at post-season testing.

Design 3

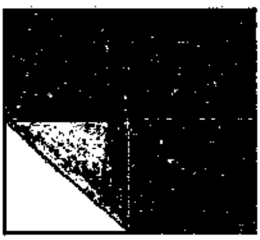

Figure 15: Block Design 3

Design 3 requires the subject to use three red sides and one red-and-white side to create the design. Guidelines are still presented on the design, and it may therefore be considered non-embedded. Table 14 provides the means and standard deviations from this item.

TABLE 14. Block Design Item 3

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		*F*-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	1.43 n.s.
PRE-SEASON	12.90	6.69	11.14	7.31	11.70	2.89	
MID-SEASON	13.22	2.37	10.64	2.40	10.41	1.94	
POST-SEASON	11.11	3.63	10.64	3.88	10.01	2.17	

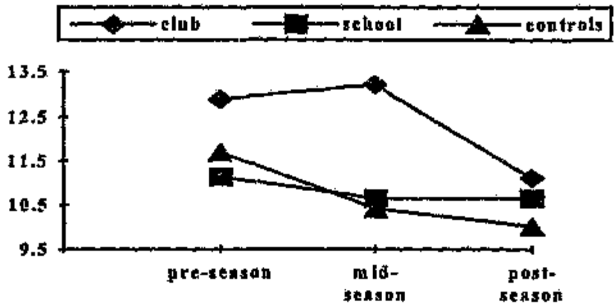

Figure 16 W.I.S.C.-R. Block Design 3

No significant overall main effect was found for time, nor for players as opposed to controls, although the latter approached significance at the 5% level. No significant main effect was noted for positions.

Neither the players nor controls demonstrated a significant increase in speed over time, although the latter's increase in speed approached significance, also at the 5% level. This was also found for the distribution of players. Post-hoc ANOVA revealed a significant difference between the club players and both the controls and the school players at the mid-season stage of testing, with the club players performing significantly slower than both groups. No significant difference was found between the school players and the controls. ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable failed to demonstrate that the pre-season score has a significant effect on the mid-season score, but confirmed the significant discrepancy between club players and the other two groups ($F = 7.09$, $p < 0.002$).

Design 6

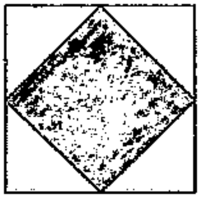

Figure 17: Block Design 6

This design requires the subject to reproduce a diamond-shaped figure using four blocks. No guidelines are apparent in the design, which is therefore considered embedded. The design is reproduced using all four blocks' red-and-white sides facing up, although an organic subject may attempt to use only one block's red side and rotate the block in an attempt to reproduce the design.

On this item, the school players (who may be considered quasi-controls) were found to slow down over time before an improvement found in post-season testing. Table 15 provides the means and standard deviations from this item.

TABLE 15. Block Design Item 6

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		*F*-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	1.78 (N.S.)
PRE-SEASON	27.75	20.14	28.26	26.05	19.81	9.98	
MID-SEASON	26.48	12.29	30.17	25.74	18.56	10.62	
POST-SEASON	24.20	16.25	21.05	16.29	15.35	7.21	

- The very large standard deviations found for the soccer playing subjects indicate that there were subjects who were unable to complete the design by the time limit, even in the mid-season and post-season administrations.

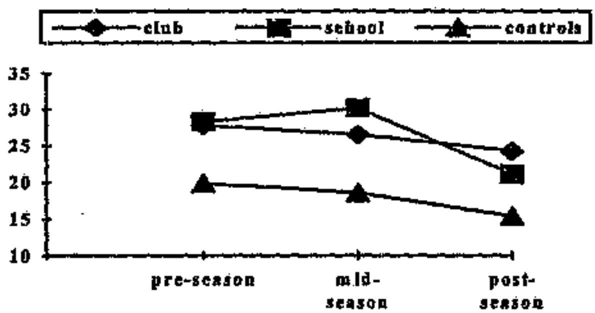

Figure 18: W.I.S.C.-R. Block Design 6

No significant overall main effect was found for time, nor for positions, although forwards were found to have performed significantly slower than controls ($p < 0.05$). Controls were found to have performed significantly faster than both club and school players ($p < 0.05$).

Neither the players nor controls demonstrated a significant increase in speed over time, which also applies to the distribution of players. Post-hoc ANOVA revealed no significant difference between the players and controls at any stage of testing. ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrated that the pre-season score has a significant effect on the mid-season score ($F = 26.19$, $p < 0.0001$), but no discrepancy was found between players and controls.

Design 9

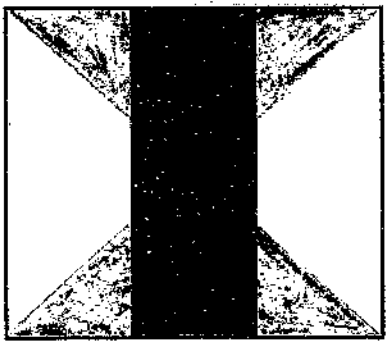

Figure 19: Block Design 9

This design employs nine blocks, and is considered to be an embedded design. Table 16 provides the means and standard deviations from this item.

TABLE 16. Block Design Item 9

	CLUB (N = 23)		SCHOOL (N = 26)		CONTROLS (N = 21)		F-value
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	6.44 ***
PRE-SEASON	95.28	34.25	62.92	33.63	75.26	33.43	
MID-SEASON	79.81	40.44	60.30	32.81	64.45	27.56	
POST-SEASON	68.45	35.19	49.49	25.03	56.98	23.64	

*** $p < 0.002$

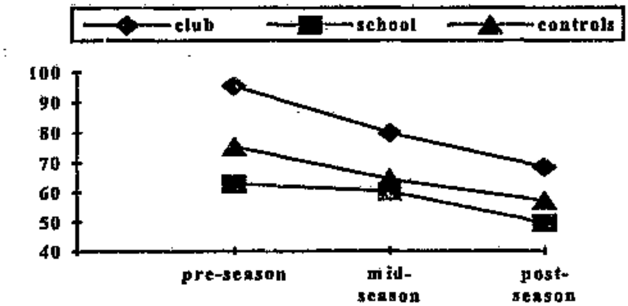

Figure 20. W.I.S.C.-R. Block Design 9

A significant overall main effect was found for time ($F = 6.44$, $p < 0.002$), in pre-season/post-season comparisons. A significant main effect ($F = 16.05$, $p < 0.0001$) was also found for players vs. controls, where club players performed significantly slower than both school players and controls. No significant difference was found between controls and school players, and no significant main effect was noted for positions.

Only the club players demonstrated a significant increase in speed over time ($F = 4.05$, $p < 0.02$), which also applies to the distribution of players. Post-hoc ANOVA revealed a significant difference between the club and school players (with the former significantly slower) at the pre-season stage of testing. ANCOVA using the mid-season test as the covariate and post-season test as the dependent variable demonstrated that the pre-season score has a significant effect on the mid-season score ($F = 50.36$, $p < 0.0001$), but no discrepancy was found between players and controls.

SUMMARY OF RESULTS

HIGHLY SPEEDED TESTS:

Finger-tapping: Club players were the only subjects who showed a significant increase in speed over time on both administrations, but no significant discrepancy was found between the club players, school players and controls at any stage during the three testings. The club players performed fastest overall, although they were not the quickest at the first testing.

C.N.E.I.

Item 1: Only the school players showe‘ a significant increase in speed over time on all three administrations (right-hand, left-hand and both-hands). The club players showed a significant increase in speed on the single-hand administrations, while the controls increased their speed only on the left-hand administration. The club players generally performed quickest on this task, although no significant discrepancy was found between any group at any stage during the testing.

Item 2: Here the controls performed significantly faster than the players, while the school players constit ıted the only group to shows a significant increase in speed over time. During the mid-season testing the controls were found to be performing significantly faster than t' school players.

Item 3: No subjects demonstrated a significant increase in speed over time on this item.. However, the controls performed significantly faster than the club players, and generally performed quickest.

Item 4: The club and school players showed a significant increase in speed over time, although they did not perform significantly faster than the controls. Despite starting slowest, the club players performed quickest at post-season assessment. No significant difference was found between players and controls at any stage during the testing.

Pegmoving: Only the club players demonstrated a significant increase in speed over time, although they performed significantly slower than their school counterparts on both administrations, and significantly slower than the controls on the left-hand administration. On the whole it was the school players who performed quickest.

MODERATELY SPEEDED TESTS

Trail-Making: Part A: No group of subjects demonstrated a significant increase in speed over time, neither did any group perform significantly faster than any other. The school players actually showed a slight regression from mid-season to post-season testing, although overall they performed quicker from first to last testing.

Part B: The club and school players demonstrated a significant increase over time, although both performed slower than the controls initially. No significant difference was found at any stage during testing between players and controls.

Block Design: Item 1: No group of subjects demonstrated a significant increase in speed over time, although the controls performed quickest on all three tests. In addition, the controls demonstrated a fairly uniform improvement while both club and school players regressed from pre-season to mid-season testing, after which they improved.

Item 3: No group of subjects demonstrated a significant increase in speed over time, although the controls' increase in speed approached significance. The controls were the quickest on the post-season testing, while the school players were quickest initially. At mid-season testing the club players performed significantly slower than the other two groups, and they showed a slight regression at this point.

Item 6: On this item the controls out-performed both soccer-playing groups, while no group showed a significant increase in speed over time. The school players actually showed a slight regression in performance at mid-season, but an overall improvement.

Item 9: On this item the school players performed consistently fastest, and club players were found to have performed significantly slower than both other groups. However, the club players were the only ones to show a significant increase in speed over time.

CHAPTER 5

DISCUSSION

The subjects in all the samples were expected to have demonstrated an improved performance over the course of the testing, if not as a result of practice effects, then as a result of maturation. This twofold nature of improvement in performance is likely to render differentiation difficult, in terms of which was more likely to have resulted in such an improvement, but it would cause a lack of improvement over time to be viewed with some concern.

There were slight discrepancies between the length of time that comprised the club and school soccer seasons, with the latter being approximately two-thirds of the length of the former. The periods over which the controls were tested were arranged to correspond exactly to those over which the club players were tested.

Since none of the subjects in the sample used was concussed during the course of the season, any deficit in performance is more likely to have resulted from the cumulative effect of contact between ball and head, following the hypotheses stated earlier. Other head injuries incurred outside soccer were not reported, although the possibility does exist that minor head injuries were incurred but these were thought not to be noteworthy by parents and as such were not reported to the present writer. If we may discount this as a possibility, and no significant improvement is found in soccer players but indeed in controls, we may hypothesise that soccer play exposes its participants to the risk of minor head injury effects and sequelae without the necessity of an overt concussive injury being sustained.

Soccer played by the subjects in the age level of this sample is not played with the same sort of intensity as it is in older players. As such, players in this age group are less likely to "head" the ball if this eventuality can be avoided, whereas older players in seeking to maximise their advantage on the playing field will be more likely to "head" the ball than allow it to drop to a level where an opponent may successfully compete for possession of it. Therefore, the players in this study may be rated in a lower-intensity "heading" group, and if deficits are found in this group, they may point to the possibility that older players are susceptible to more serious disruptions of cognitive functioning.

THE HIGHLY SPEEDED TESTS

The highly speeded tests seemed to favour the soccer playing subjects over the controls, which may be a result of the former possessing more manual dexterity given their ability to excel in sport. As a result, these tests may have limited usefulness for future research in this field, since all the subjects tended to show roughly equivalent practice effects. The controls and quasi-controls were even observed to show smaller practice effects than the club players on certain tests.

On the highly speeded tests, which may be considered to require less cognitive processing than the moderately speeded tests, significant improvements were found for most of the tests, which mostly applied to the soccer playing subiects rather than the controls. In some instances, the controls were seen to have performed faster than the players, which would suggest that they reached the ceiling level of their speed earlier than the other groups, although post-hoc analysis of variance demonstrated that differences were not significant at the earlier stages. On most of the highly speeded tests the players demonstrated a significant improvement over time. The club players showed such improvements more than the school players, but mostly would have started out performing more slowly than their counterparts.

The Finger tapping test showed a fairly consistent pattern of the players performing faster than the controls, and improving their speed to roughly the same degree. This may have been expected given the nature of the tests, being more psychomotor in nature, with the likelihood that more gifted sports participants may be naturally more dextrous than other children.

On the C.N.E.I., it is noteworthy that on items 2 and 3, the control subjects performed significantly faster than both playing groups, while on item 2 the controls' improvement approached significance. Therefore here the controls reached their ceiling almost immediately while the others performed slower. The controls were actually found to have performed significantly faster than the school players at the mid-season stage, pointing to a reduced learning effect in the latter group at this stage. Only the school players demonstrated a significant improvement on one of these two items, namely item 2, which indicates that not only did the playing subjects generally perform slower than the controls, but they were unable to register a significant improvement in speed over time. On the most complex component of item 1, (the both-hands administration) the club players were again unable to register a significant practice effect. This may suggest the possibility of subtle impairment that is already present in the club players, who may be considered to have been exposed to more soccer play before the study even began, as well as more soccer play during the course of the present study.

The peg moving task results were interesting in that the club players comprised the only group to register a significant improvement in speed over time. This notwithstanding, they performed significantly slower than the quasi-controls and controls. This is suggestive of a possibility that these subjects have already suffered some form of impairment owing to previous exposure to the game, which is confirmed by the finding that the club players performed significantly slower than the school players and controls at the pre-season stage of testing, while the controls performed faster than both groups at the mid-season stage.

On the majority of the highly speeded tests, the control subjects did not perform any better over time, which gives cause for concern given that they were not demonstrated to have out-performed the players significantly initially and therefore by doing so did not deny themselves adequate scope for improvement. Tests designed to elicit practice effects should differentiate between experimental groups and control groups in terms of the presence or absence of these practice effects, or alternately if practice effects are found for both groups, in terms of the magnitude of these effects. In some studies the practice effects on experimental subjects would be expected to exceed those of the control groups, while in studies of this nature, the reverse is expected. This may suggest that the tests that did not find such results have limited differential usefulness in this sort of research, and other tests with a more cognitive component may be included in future batteries investigating these type of phenomena. The battery of tests used in the Shuttleworth-Jordan *et al.* (1993) consisted of more cognitive tests, but these particular tests were not used in the present study because of their verbal nature.

THE MODERATELY SPEEDED TESTS

On most of the moderately speeded tests, where more cognitive processing was required, very few significant increases in speed over time were found, and when so were noted in the performances of the club players. Diminished practice effects were seen from club players on practically all the moderately speeded tests, which accords with the initial hypothesis, and school players demonstrated similar results. Again here the failure of the control subjects to register significant practice effects is of concern given that they performed better than the players, but not significantly so.

The Trail-Making tests elicited no significant discrepancy between the speed of performance between players and controls, although on part B, the soccer playing subjects demonstrated a significant practice effect. Compared to the results in a study by Leckliter, Forster, Klonoff and Knights (1992) conducted on children in the USA, all the subjects in this study performed slower, but it must be noted that the subjects in this study were assessed on the adult Trail-Making Test, which is nearly twice as long as the test for older children administered in the Leckliter *et al.* study.

The Block design items were utilised because of their cognitive component, as opposed to the psychomotor speed component that may be considered the sole important component of the highly speeded tests. Non-verbal problem-solving skills are assessed with this test, in terms of the analysis and synthesis of non-verbal information. Lowered scores or practice effects on these items may be the precursor to academic difficulties owing to impaired concentration or reduced learning ability.

Block design 1 would appear to have use for this type of research only as an example or a "warm-up" item for the rest of the test. No statistical significance was registered on this test in terms of players vs. controls, nor in terms of practice effects, which suggests that the item may not have had sufficient discriminative abilities. However, it may not be prudent to discard this item from future research, as its value as an introduction to the requirements of the test seems to be high.

On block design 3, the controls were the only group to register results approaching significance both in terms of speed of performance and in terms of practice effect. Club players were also found to be performing significantly slower than the controls and quasi-controls at the mid-season stage of testing.

On block design 6, players performed worse than controls. This particular design is one of those comprising a figure described as "embedded" (Walsh, 1985) and therefore more sensitive to brain damage, which means that persons with cognitive dysfunction or cognitive limitations may find this design particularly difficult to reproduce. Often a tendency to rotate one solid coloured block in order to achieve a diamond shape, as opposed to using four half-coloured, half-white blocks, is seen, and this response set is often perseverated in cases of brain damage.

On design 9, the club players performed significantly slower than the school players and controls, which qualifies their significant practice effect. In pre-season testing particularly the club players were found to have performed significantly slower than their school counterparts.

It was seen that for some tests, players performed significantly quicker than the controls, which may have had an influence over the reduced practice effects found for these players. It may be that children who are capable of playing sport at a fairly high level are naturally more dextrous than others, viz. the controls in this study, as alluded to earlier. Unfortunately, no access to the individual subjects' academic records was available, which would have increased understanding of particularly the performances on the moderately speeded tests. It is plausible that the control group was cognitively more "competent" from the start than were the soccer players.

SCHOOL vs. CLUB PLAYERS

School players generally performed better than club players, although on more detailed post-hoc analysis, different positions among school and club players showed poorer performances in terms of practice effects. This trend was particularly found in the more cognitively challenging tests, such as block design. Since school players may be considered to be quasi-control subjects, these results would appear to be very significant. The implication of these results is that less impairment of performance is noted with players who are exposed to less soccer play. It must be noted that no grossly defective results were found in this study.

Another reason why club players may have been more at risk is that their club practices were held during the evenings. This might result in impaired concentration as fatigue sets in after a full day of activities, and possible lapses of judgement and a lowered adherence to "safer" heading techniques. While this may be less of a concern for children than for adults, it would appear to be a necessary consideration for the adult game, particularly at amateur level where participants have other careers. It may be argued that had matches been held during the evening rather than practices, this risk would increase owing to the more competitive environment of a sport match. However, competition between the club subjects in this study for places in their respective teams for matches was of a moderate-to-high intensity, since there is only one club team per age group, and practices would seem to have been tantamount to matches in terms of intensity. Most club players would be likely to play soccer at school as well as at their clubs, thereby being expected to play almost double the amount of the game.

The school players, on the other hand, would have been able to play soccer, albeit for a lower team, if not selected for the premier teams. However, some sort of social censure may follow being "dropped", and the intensity of the soccer play in school may not be far short of that in club players. It is therefore likely that the amount of soccer played is an important factor in this study.

On some tests, however, it was the school players who showed a deterioration over time. The incidence of this was very limited, and confined to pre-season/mid-season comparisons, although it may be significant.

THE POSITIONS

Among the distribution of positions, the midfielders, who were observed to "head" the ball more frequently than most other players, showed poorer performances of varying degrees of significance on many of the tests. The players were generally loath to head the ball, which seems to be common to most younger soccer players. While this result may suggest that midfield players are most likely to sustain disruptions of neuropsychological functioning, this would need to be verified on older subjects to ascertain whether or not there is a positional risk in addition to the risk incurred by frequent "headers" of the ball, in a study similar to that of Witol and Webbe (1994). In soccer played by older individuals, there would seem to be a fairly general distribution of "headers", although defenders appear to have more work to do in heading the ball than do other players.

Club midfielders showed fairly anomalous performances. They tended to be the most likely of the soccer-playing subjects to show a significant improvement in speed. However, it would appear that they are the subjects whose performances had a negative impact on the midfielders' overall scores, especially initially. This suggests that they showed a significant improvement largely because they performed very slowly initially. This therefore brings into question whether or ne: it is possible to describe these improvements as true practice effects, and may therefore indicate that what damage there is had been done before the study started, and that these frequent headers of the ball may experience subtle difficulties in learning and adapting to new tasks and information. The players themselves were not observed to have demonstrated any form of test resistance initially, merely curiosity, and most of the club subjects tended to be competitive and wishing to "out-do" their team-mates.

The number of goalkeepers (N = 3) included in this study was smaller than desirable, and therefore their results may not have been likely to reach significance. This was inevitable given that testing four teams would only provide a maximum sample size of four goalkeepers. The club teams may have been expected to have more than one goalkeeper, but this was not found to be the case. Since this is a specialist position, reserve goalkeepers would be scarce at this level as they would not get to participate in matches unless the first choice 'keeper was injured. Alternatively, one of the outfield players may assume the role of reserve goalkeeper, but would then have to be considered as a player in his regular position rather than as a goalkeeper.

DO SPORTS PARTICIPANTS HAVE AN ADVANTAGE ON CERTAIN TESTS?

On some of the tests, the club players and school players performed not only better than controls initially, but improved at the same or a better rate. This was especially noted for the tests termed "highly speeded", and may imply that these sorts of tests may have limited usefulness for studies involving testing people of varying degrees of dexterity. Thus it may be presupposed that a gifted sport participant would perform better on a test of psychomotor speed than a gifted scholar. This may mean that the school players in this study, representing perhaps a more allround individual who was capable of excelling in sport and academics, may be more representative of children in South Africa.

The present writer observed that the school players in this study understood what was required of them in the moderately speeded tests more quickly than their club counterparts in the initial testing. It may be that the school subjects are functioning at a "higher" level cognitively than the club players, but without the longitudinal academic performances available for scrutiny, it is unclear whether or not both groups started at the same academic achievement levels and one has improved more than the other over time (or one has regressed or remained static). This may be important to consider in further studies in order to attempt to chart subtle neuropsychological deficits resulting from more soccer play.

OTHER VARIABLES

Handedness was found to have a significant impact on some of the test performances. Some significant discrepancies were found with respect to dominant hand, although the number of left-handers in the sample was small. Specific tests where these discrepancies were found were mostly on the single-hand administration of the highly speeded tests, although some of the block design tests showed similar results. Generally it was found that right-handed subjects performed significantly more quickly on the task using the right-hand, as did left-handers on those with the left-hand. However, the right-handed subjects were observed to perform better on the block design tests than their left-handed counterparts.

CHAPTER 6

CONCLUSIONS

From the results of this study, we may conclude that there is no unequivocal evidence that soccer play exposes its participants to a significant risk of disruptions to their cognitive neuropsychological functioning. However, there are indications that in the more cognitive tests, the players who have the most exposure to soccer play show a reduction in practice effects that may adumbrate cognitive difficulties later in life. Midfield players in this age group appear to be at more risk than players in other positions.

6.1. LIMITATIONS OF THE STUDY

This study was limited in that the number of subjects used is fairly small. In addition, the tests of psychomotor speed, i.e. finger-tapping, the Clinical Neuropsychological Evaluation Instrument and the Annett's peg-moving task, did not demonstrate a usefulness in terms of differentiating practice effects found between controls and soccer playing subjects.

Socio-economic variables were not taken into account, in that all the subjects in the study come from families in the middle to upper socio-economic brackets, which are considered less likely to be susceptible to head injury and neuropsychological dysfunction.

More uniformity in testing periods of the quasi-control subjects and the club players may have been advisable, in that the club players and controls were tested and retested over a slightly longer period than were the school players.

6.2. FUTURE IMPLICATIONS

Future studies may study the incidence of disruptions of neuropsychological functioning at different levels of football-playing proficiency, as well as in different countries, which may employ different styles of soccer. In English soccer, for example, the ball is played in the air much of the time (known as the "long-ball" approach), while in countries such as Brazil, the skills of the players are such that the ball is not played in the air to the same extent. This would suggest that players in England may be more at risk of sustaining concussive injuries and disruptions of neuropsychological functioning than those in Brazil.

Future studies may also consider employing longitudinal investigations of neuropsychological disruptions. Pilot studies of padding the goal posts would seem to be important, although this may be more applicable to the adult soccer game as opposed to children in terms of the speed of impact with the goal post. Nevertheless, a safety precaution such as this should be applied to all levels of the game. Another potentially more fruitful method of approaching such a study is to arrange to test the subjects exclusively in more suitable test venues, such as at their own homes. This would afford the opportunity to use a more extensive battery of tests, as well as reduce the possibility of the subject becoming distracted and losing concentration because he fears he is losing out on the chance to practice, albeit for only a short time, with his team-mates.

It is recommended that the rules of soccer be modified to prevent children up to a certain age (possibly early teens) from heading the ball. This would mean that kicking the ball above a certain height off the ground, when players are nearby, be made an infringement to reduce the possibility of the head hitting the ball. These rules presently apply to field hockey where if players are not in proximity to the ball, it is permissible to lift the ball above knee height, while lifting the ball is an infringement if other players are in immediate proximity.

REFERENCES

Abreau, F., Templer, D.I., Schuyler, B.A., & Hutchison, H.T. (1990). Neuropsychological assessment of soccer players. *Neuropsychology, 4*, 175-181.

Adams, I. D. (1976) Brain Damage in Sport. *Lancet*, 585.

Adams, W. (1990). Effects of mild head injury on children's academic performance. Paper presented at the North Coast Society of Paediatric Psychology. Detroit, MI. Cited in Beers (1992, below).

Annett, M (1992a). Assessment of Laterality. in J.R. Crawford, D.M. Parker and W.M. McKinlay (eds.) *A handbook of Neuropsychological Assessment* (51-68). Hove, Hillsdale: Lawrence Erlbaum Associates.

Annett, M. (1992b) Five tests of hand skill. *Cortex*, *28*, 583-600

Anzil, F. (1979) The football player's jumping abilities and head playing. in Vecchiet L. (ed) *First International Congress of Sports Medicine applied to football.* Rome, February 6 to 9, Rome, D. Guenella, 643-652. Cited in Tysvaer and Storli (1989, below).

Barth, J.T., Alves, W.M., Ryan, T.V., Macchiochi, S.N., Rimel, R.W., Jane, J.A., & Nelson, W.E. (1989) Mild head injury in sports: Neuropsychological sequelae and recovery of function. in H.S. Levin, H.M. Eisenberg & A.L. Benton (Eds.) *Mild Head Injury* (257-275) New York, Oxford: Oxford University Press.

Batchelor, J., Harvey, A.G., & Bryant, R.A. (1995). Stroop Colour-Word test as a measure of attentional deficit following minor head injury. *The Clinical Neuropsychologist 9*(2), 180 -186.

Bawden, H.N., Knights, R.M., & Winogron, H.W. (1895). Speeded performance following head injury in children. *Journal of Clinical and Experimental Neuropsychology, 7*, 34-54.

Beers, S.R. (1992). Cognitive effects of mild head injury in children and adolescents. *Neuropsychology Review, 3* (4) 281-320.

Bixby-Hammett, D.M. (1983). Head injuries in the equestrian sports. *Physician and Sports Medicine, 11*, 82-86.

Bohnen, N., Jolles, J. & Twijnstra, A. (1992). Modification of the Stroop Colour-Word Test improves differentiation between patients with minor head injury and matched controls. *The Clinical Neuropsychologist, 6*, 178-188.

Bohnen, N., Twijnstra, A. & Jolles, J. (1993). Persistence of postconcussive symptoms in uncomplicated mildly head-injured patients: A prospective cohort study. *Neuropsychiatry, Neuropsychology and Behavioural Neurology, 6*, 193-200.

Cantu, R.C. & Voy R. (1995). Second Impact Syndrome: A risk in any contact sport. *The Physician and Sportsmedicine, 23*(6) 27-34.

Carlsson, G.S., Svärdsudd, K. & Welin, L. (1987). Long-term effects of head injuries sustained during life in three male populations. *Journal of Neurosurgery, 67*, 197-205.

Chadwick, O., Rutter, M., Brown, G., Shaffer, D., & Traub, M. (1981). A prospective study of children with head injuries: II. Cognitive sequelae. *Psychological Medicine, 11*, 49-61)

Cimino, C.R. (1994). Principles of neuropsychological interpretation. in Vanderploeg, R.D. (Ed) *Clinician's Guide to Neuropsychological Assessment* (69-106) Hove, Hillsdale: Lawrence Erlbaum Associates.

Dailey, S.W. & Barsan, W.G. (1992). Head injuries in soccer: A case for protective headgear. *The Physician and Sportsmedicine, 20*(8) 79-85.

Dikmen, S., McLean, A., & Temkin, N. (1986). Neuropsychological and psychosocial consequences of minor head injury. *Journal of Neurology, Neurosurgery and Psychiatry,49,* 1227-1232.

Ewing, R., McCarthy, D., Gronwall, D. & Wrightson, P. (1980). Persisting effects of minor head injury observable during hypoxic stress. *Journal of Clinical Neuropsychology, 2*, 147-155.

Fields, K.B. (1989). Head injuries in soccer. *The Physician and Sportsmedicine, 17*(1), 69-73.

Foster, J.B., Tilley, P.J.B., & Leiguarda, R. (1976). Brain damage in national hunt jockeys. *Lancet,1*, 981-983.

Franzen, M.D., Paul, D. & Iverson, G.L. (1996) Reliability of alternate forms of the Trail Making Test. *The Clinical Neuropsychologist,10*(2), 125-129.

Fuld, P.A. & Fisher, P. (1977). Recovery of intellectual ability after closed head injury. *Developmental Medicine and Child Neurology, 17*, 495-502.

Genuardi, F.J. & King, W.D. (1995). Inappropriate discharge instructions for youth athletes hospitalised for concussion. *Pediatrics, 95*(2), 216-218.

Gerberich, S.G., Priest, J.D., Boen, J.R. et al. (1975). Concussion incidences and severity in secondary school varsity footballplayers. *American Journal of Public Health, 73*, 1370-1375. Cited in Wilberger (1993, below).

Gouvier, W.D., Cubic, B., Jones, G., Brantley, P. & Cutlip, Q. (1992). Postconcussion symptoms and daily stress in normal and head-injured college populations. *Archives of Clinical Neuropsychology, 7*, 193-211.

Greenspan, A.I. & MacKenzie E.J. (1994) Functional outcome after paediatric head injury. *Pediatrics, 94*(4), 425-432.

Gronwall, D. (1989). Cumulative and persisting effects of concussion on attention and cognition. in H.S. Levin, H.M. Eisenberg & A.L. Benton (Eds.) *Mild Head Injury* (154-162). New York, Oxford: Oxford University Press.

Gronwall, D. & Wrightson, P. (1975). Cumulative effects of concussion. *Lancet, 2*, 995-997.

Gulbrandsen, G.B. (1984) Neuropsychology of light head injuries in older children 6 months after trauma. *Journal of Clinical Neuropsychology, 6*, 257-268.

Haglund, Y. & Bergstrand, G. (1990). Does Swedish amateur boxing lead to chronic brain damage? II A retrospective study with CT and MRI. *Acta Neurologica Scandinavica 82*(4), 297-302.

Haglund, Y., Edman, G., Murelius, O., Oreland, L. & Sachs, E. (1990). Does Swedish amateur boxing lead to chronic brain damage? I A retrospective medical, neurological and personality trait study. *Acta Neurologica Scandinavica 82*(5), 245-252.

Haglund, Y. & Persson, H.E. (1990) Does Swedish amateur boxing lead to chronic brain damage? III A retrospective clinical neurophysiological study. *Acta Neurologica Scandinavica 82*(6), 353-360.

Janda, D.H., Bir, C., Wild, B., Olson, S., & Hensinger, R.N. (1995) Goal post injuries in soccer. *American Journal of Sports Medicine, 23*(3), 340-344.

Jennett, B. (1989). Some international comparisons. in H.S. Levin, H.M. Eisenberg & A.L. Benton (Eds.) *Mild Head Injury* (23-36). New York, Oxford: Oxford University Press.

Jordan, S.E., Green, G.A., Galanty, H.L., Mandelbaum, B.R. & Jabour, B.A. (1996). Acute and chronic brain injury in US national team soccer players. *American Journal of Sports Medicine, 24*(2), 205-210.

Kelly, J.P., Nichols, J.S., Filley, C.M., Lillehei, K.O., Rubinstein, D. & Kleinschmidt-DeMasters, B.K. (1991). Concussion in sports: guidelines for the prevention of catastrophic outcome. *Journal of the American Medical Association, 266*(20) 2867-2869.

Kraus, J.F. and Nourjah, P. (1989). The epidemiology of mild head injury. in H.S. Levin, H.M. Eisenberg & A.L. Benton (Eds.) *Mild Head Injury* (8-22). New York, Oxford: Oxford University Press.

Kujala, U.M., Taimela, S., Antti-Poika, I., Orava, S., Tuominen, R. & Myllynen, P. (1995) Acute injuries in soccer, ice hockey, volleyball, basketball, judo and karate: analysis of National Registry data. *British Medical Journal, 311*, 1465-1468.

Lampert, P.W. & Hardman, J.M. (1984). Morphological changes in brains of boxers. *Journal of the American Medical Association, 251*, 2676-2679.

Leblanc, K.E. (1994). Concussion in sports: Guidelines for return to competition. *American Family Physician, 50* (4), 801-806.

Leckliter, I.N., Forster, A.A., Klonoff, H. & Knights, R.M. (1992). A review of reference group data from normal children for the Halstead-Reitan Neuropsychological test battery for older children. *Clinical Neuropsychologist,6*(2), 201-229.

Leininger, B.E, Gramling, S.E., Farrell, A.D., Kreutzer, J.S. & Peck, E.A. (1990). Neuropsychological deficits in symptomatic minor head injury patients after concussion and mild concussion. *Journal of Neurology, Neurosurgery and Psychiatry, 53* (4), 293-296.

Levin, H.S., Ewing-Cobbs, L. & Fletcher, J.M. (1989). Neurobehavioural outcome of mild head injury in children. in H.S. Levin, H.M. Eisenberg & A.L. Benton (Eds.) *Mild Head Injury* (189-213). New York Oxford: Oxford University Press.

Lindsay, K., McLatchie, G., & Jennett, B. (1980). Serious head injury in sport. *British Medical Journal, 291*, 789-791.

Majovski, L.V., Tanguay, P., Russell, A., Sigman, M., Crumley, K., & Goldenberg, I. (1979). Clinical Neuropsychological Evaluation Instrum-ѐt: A Clinical Research Tool for Assessment of Higher Cortical Deficits in Adole-. .nts. *Clinical Neuropsychology, Third Quarter*, 10-18.

Martini, D.R., Beers, S.R., & Ryan, C.M. (1990) Long-term neuropsychologic sequelae of mild head injury in young children: Effects of locus of injury and biomedical complications. Paper presented at the North Coast Society of Paediatric psychology. Detroit, MI. Cited in Beers (1992, above).

Mathews, W.B. (1972). Footballer's migraine *British Medical Journal, 2*, 326.

McLatchie, G. & Jennett, B. (1994). H-ad injury in sport. *British Medical Journal,308*, 1620-1624.

Nathan, M., Goedeke, R., & Noakes, T.D. (1983). The incidence and nature of rugby injuries experienced at one scho. during the 1982 rugby season. South African Medical Journal, 64, 132-137.

National Health and Medical Research Council (referred to as N.H.M.R.C. in the text) (1993). Football injuries of the head and neck: draft for consultation purposes. Canberra, 1993.

Nelson, W.E., Jane, J.E. & Gieck, J.H. (1984). Minor head injury in sports: a new system of classification and management. *The Physician and Sports Medicine, 12*(3), 103-107.

Oddy, M., Humphrey, M., & Uttley, D. (1978). Subjective impairment and social recovery after closed head injury. *Journal of Neurology, Neurosurgery and Psychiatry, 41*, 611-616.

O'Donnell, J.P., M...Gregor, L.A., Dabrowski, J.J., Oestreicher, J.M., and Romero, J.J. (1994). Construct validity of neuropsychological tests of conceptual and attentional abilities. *Journal of Clinical Psychology, 50*(4), 596-600.

Oppenheimer, D.R. (1968). Microscopic lesions in the brain following head injury. *Journal of Neurology, Neurosurgery and Psychiatry, 31*, 299-306.

Pang, D. (1989). Physics and Pathophysiology of Closed Head Injury. In Lezak, M.D. (ed.) *Assessment of the behavioural consequences of head trauma.* New York: A.R. Lisse.

Parker, R.S., & Rosenblum, A. (1996) IQ loss and emotional dysfunction after mild head injury incurred in a motor vehicle accident. *Journal of Clinical Psychology 52*(1) 32-43.

Reid, D.C. (1992). *Sports Injury - Assessment and Rehabilitation.* New York: Churchill Livingstone.

Roux, C., Goedeke, R., Visser, G.R., van Zyl, W.A., & Noakes, T.D. (1987). The epidemiology of schoolboy rugby injuries. *South African Medical Journal, 71*, 307-313.

Ruff, R.M., I [illegible] S., Mattis, S., High, W.M., Marshall, L.F., Eisenberg, H.M. & Tabaddor, K. (1989). Recov[illegible]y of Memory after Mild Head Injury: A Three-Center Study. in H.S. Levin, H.M. Eisenberg & A.L. Benton (Eds.) *Mild Head Injury* (176-188). New York, Oxford: Oxford University Press.

Rutherford, W.H. (1989). Postconcussion symptoms: Relationship to acute neurological indices, individual differences, and circumstances of injury. in H.S. Levin, H.M. Eisenberg & A.L. Benton (Eds.) *Mild Head Injury* (217-228). New York, Oxford: Oxford University Press.

Rutter, M., Chadwick, O., Shaffer, D., & Brown, G. (1980). A prospective study of children with head injury. I. Design and Methods. *Psychological Medicine, 10*, 633-645.

Schneider, K., & Zernicke, R.F. (1988). Computer simulation of head impact: estimation of head-injury risk during soccer heading. *International Journal of Sports Biomechanics, 4*, 358-371.

Segalowitz, S.J., & Brown, D. (1991). Mild head injury as a source of developmental disabilities. *Journal of Learning Disabilities, 24*, 551-559.

Shuttleworth-Jordan, A.B., Balarin, E., & Puchert, J. (1993). Mild head injury effects in rugby: Is playing the game really worth the cost? Paper presented at the International Neuropsychological Society 16th European Conference, Island of Madeira (Portugal).

Smodlaka, V.N. (1984). How dangerous is heading? *FIFA Magazine, December* 17-18. Cited in Tysvaer and Storli (1989, below).

South African Rugby Football Union statistics on injuries in South African rugby, 1994 and 1995 - personal communication.

Tan, N., & Kakular, B.A. (1981). Pathology of Head Injuries. in T.R. Dinning, T.J. Connelley (eds.) *Head Injuries*. Brisbane: John Wiley.

Thomassen, A., Juul-Jensen, P., Olivarius, B.D.F., Braemer, J., & Christensen, A.L. (1979). An electroencephalographic and neuropsychological examination of 53 former boxers. *Acta Neurologica Scandinavica, 60*, 352-62.

Tysvaer, A F. & Løchen, E.A. (1991). Soccer Injuries to the Brain: A neurologic study of former soccer players. *American Journal of Sports Medicine, 19*(1).

Tysvaer, A.T. & Storli, O.V. (1989). Soccer injuries to the brain: A neurologic and electroencephalographic study of active football players. *American Journal of Sports Medicine, 17*(4) 573-578.

Tysvaer, A.T., Storli, O.V. & Bachen, N.I. (1989). Soccer injuries to the brain: A neurologic and electroencephalographic study of former players. *Acta Neurologica Scandinavica, 80*(2) 151-156.

van Veldon, D. (1990). *The Prevention and Treatment of Sports Injuries*. South Africa: Medical Association of South Africa.

van Zomeren, A.H. & Brouwer, W.H. (1992). Assessment of Attention. in J.R. Crawford, D.M. Parker & W.M. McKinlay (eds.) *A handbook of Neuropsychological Assessment*. 241-266. Hove, Hillsdale: Lawrence Erlbaum Associates.

Vickers, D., Vincent, N. & Medvedev, A. (1996). The geometric structure, construction and interpretation of path-following (trail-making) tests. *Journal of Clinical Psychology, 52*(6) 651-661.

Walsh, K.W. (1985). *Understanding Brain Damage*. 242-243. Singapore: Longman Singapore Publishers.

Wilberger, J.E. (1993). Minor Head Injuries in American Football: Prevention of Long Term Sequelae. *Sports Medicine,15*(5) 338-343.

Witol, A. & Webbe, F. (1994). Neuropsychological deficits associated with soccer play. *Archives of Clinical Neuropsychology, 9*(2) 204-205.

Yarnell, P.R. & Lynch, S. (1973). The "ding": amnestic states in football trauma. *Neurology (Minnesota),23* 196-197.

APPENDIX 1

CLINICAL NEUROPSYCHOLOGICAL EVALUATION INSTRUMENT

(MAJOVSKI ET AL., 1979)

A. Touch each of your fingers in turn with the thumb like I'm doing. Now the other hand. Then both hands. [Then test] Now I want you to touch all the fingers of your right hand with your right thumb 20 times as quickly as you can. Now the left hand. Now both hands.

Score:	0-	perfect performance until speed (both hands)
	1-	Mild discoordination; trouble with one hand.
	2-	Greater discoordination; both hands

B. Put both of your hands on the table with your fingers together. Now spread your fingers, and close them. Keep on doing this until I say stop. Now do it as quickly as possible, 20 times.

Score:	0-	Done perfectly even when "faster"
	1-	Done perfectly at slow speed-not at "fast"
	2-	Discoordination both slow and fast

C. Put your hands on the table in the same position as mine (one flat palm down, other clenched closed). Now alternate the positions, till I tell you to stop. Now do it as quickly as you can, 20 times.

Score:	0-	Maintains even alternating movements, at speed.
	1-	Mild loss of rhythm at speed.
	2-	Major loss of rhythm at speed.

D. Watch me and do as I do. (fist, with knuckles flat, edge, palm down) until I tell you to stop. Now do it as quickly as you can, 20 times.

Score:	0-	Maintains smooth sequence at speed
	1-	loses sequence after "faster", improves after prompting / practice.
	2-	Unable to maintain sequence after "faster" even with practice.

APPENDIX 2

ANNETT'S HANDEDNESS INVENTORY

NAME: ______________ AGE:

DATE OF TESTING:

HAND: Which hand do you use to . . .	LEFT	RIGHT
Write legibly		
Throw a ball to hit a target		
Hold a racquet in tennis or squash		
Hold a match when you strike it		
Cut with scissors		
Thread a needle		
Hold the top of a broom when sweeping		
Hold the top of a spade when using it		
Deal a deck of playing cards		
Hammer a nail into wood		
Hold a toothbrush when brushing your teeth		
Unscrew a jar		
FOOT: Which foot do you prefer to use when ...		
Kicking a football		
Hopping on one foot		
EYE: Which eye do you use when . . .		
Focusing a camera		
Looking through a telescope		

APPENDIX 3

POST-CONCUSSION SYNDROME CHECKLIST
(GOUVIER ET AL., 1992)

NAME: _______________ DATE:

Please rate the frequency, intensity and duration of each of the following symptoms based on how they have affected you today according to the following scale:

FREQUENCY	INTENSITY	DURATION
1 = Not at all	1 = Not at all	1 = Not at all
2 = Seldom	2 = Vaguely present	2 = A few seconds
3 = Often	3 = Clearly present	3 = A few minutes
4 = Very often	4 = Interfering	4 = A few hours
5 = All the time	5 = Crippling	5 = Constant

HEADACHE	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
DIZZINESS	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IRRITABILITY	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
MEMORY PROBLEMS	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
DIFFICULTY CONCENTRATING	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
FATIGUE	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
VISUAL DISTURBANCES	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
AGGRAVATED BY NOISE	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
JUDGEMENT PROBLEMS	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
ANXIETY	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

APPENDIX 4

POST-CONCUSSION CHECKLIST

(ODDY ET AL., 1978)

This is a list of difficulties and feelings which people sometimes have. Please tick in the YES column for the difficulties or feelings which you have had during the last week, and in the NO column for those which you have not.

	YES	NO
Often feel unwell		
Have blackouts		
Sometimes start to put clothes on backwards		
Sometimes knock things over		
Often have headaches		
Have trouble remembering things		
Find difficulty in becoming interested in anything		
Often lose temper		
Have felt unwanted		
Feel the need to keep things tidy		
Sometimes suffer from noise inside the head		
Often feel anxious or tense		
Suffer from dizziness		
Suffer from ringing in the ears		
Have difficulty concentrating when reading		
Have been in trouble with the law		
Sometimes bump into things		
Talk too much		
Very easily affected by alcohol		