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CONCUSSION RISK IN HIGH SCHOOL ATHLETES

A Dissertation APPROVED FOR THE
DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

BY

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Abstract

This study explores the relationships between premorbid neurological conditions (i.e. Learning Disabilities and Attention Deficit Disorders) and concussion history in 106 adolescent male athletes on three outcome measures: a standardized assessment of concussion, a reaction time test, and an information processing task. In this group, the reported incidence of at least one concussion over the course of their lifetime was 67%.

A 2 x 2 factorial design was used to explore group differences on the three dependent measures. A MANOVA found a significant interaction between the two independent variables on the reaction time test. It also identified a main effect for both neurological condition and concussion history on the reaction time test, and a main effect for neurological condition on the sideline assessment of concussion. In this sample, evidence of systematic outcomes for those with Learning Disabilities and Attention Deficit Disorders, as well as those with a history of previous concussion, is congruent with previous research and supports the need for preseason baseline testing for this special population so as to maximize the validity of the pre- and post-concussion assessment. Applications for use and implications for further research are discussed.

Concussion Risk in High School Athletes

The National Institutes of Health (NIH) consensus statement regarding physical activity and cardiovascular health recommends accumulation of at least 30 minutes of moderate-intensity physical activity on most, and preferably, all days of the week (NIH, 1995). Fulfillment of this goal is at least partially met by participation in organized sports, which are enjoyed by approximately 6 million high school age adolescents across the country each year (Lyznicki, Riggs, & Champion, 1999). Benefits of physical activity and participation in sports are related to increased physical health: moderate participation in physical activity provides significant health benefits and reduces the risk of cardiovascular disease (NIH, 1995) and obesity (Barbeau, Gutin, & Litaker, 1999; Shute, 1998). Page, Hammermeister, Scanlan, and Gilbert (1998) found that benefits also include healthier behavioral practices, indicating that school sports participation is associated with reduced incidence and frequency of adolescent health risk behaviors including cigarette smoking, illegal drug use, unprotected sexual intercourse, carrying a weapon, and attempting suicide, while other studies fail to support such a claim (Skolnick, 1993). Steptoe and Butler (1996) found that sports participation is associated with increased emotional well-being in adolescents.

Along with the benefits, however, sports participation comes with a degree of risk from injury, both minor and severe (Kelly & Rosenberg, 1997). The most common injuries sustained during sports participation are to soft tissue and bones and are related to the type of sport and the skill level of the child (Landry, 1992). Physeal injuries are those related to bone growth and are a risk for boys until approximately age 18 and in girls until approximately two years after the beginning of puberty (Lipp, 1998). Ten percent of all physeal injuries are sports-related (Krueger-Franke, Siebert, & Pfoerringer, 1992).

In addition to injuries to bones and soft tissues, there are an estimated 300,000 sports-related brain injuries of mild to moderate severity in the United States each year, the majority of which are classified as concussion (Center for Disease Control (CDC), 1997). While one in five high school athletes sustain a sports-related injury each year, approximately 1 in 100,000 sustain a catastrophic injury (Lyznicki et al., 1999). In data collected by Gerberich, Priest, Boen, Straub, and Maxwell (1983), questionnaires were mailed to 103 secondary school football teams in Minnesota and were returned by 3,063 players (81%). Concussions identified by loss of consciousness, loss of awareness, or both were reported by 19% of the players, 69% of whom returned to play that same day. Postconcussive symptoms such as headache, memory problems, and attention problems were reported by some players to persist for six to nine months following the end of the season and six cases resulted in permanent disability.

Data on deaths and catastrophic injuries has served to provide the impetus for modifications intended to reduce sports-related injuries (Cantu & Mueller, 1999). Cantu and Mueller report that sports-related injuries of all types including orthopedic injuries and injuries to the brain and spinal cord have decreased in recent decades due to changes in game rules, equipment, and training methods which were designed to prevent and minimize certain types of injuries. However, epidemiologists Thurman, Brache, and Sniezek (1998) report that sports-related brain injury continues to be a considerable health risk, important because of the large number of people injured each year, the generally young age at the time of injury, and the potential cumulative effects of those injuries. They recommend a public health approach in guiding efforts in injury prevention and control.

There have been at least 14 scales published since 1973 which provide guidelines for return to play following concussion and these guidelines have been controversial within the sports medicine community due to lack of empirical evidence (Collins, Lovell, & McKeag, 1999). In the interest of developing new guidelines, a standardized method of recording and reporting the incidence of concussion will be needed for the development of empirically driven standards for determining the severity of concussion, the prescription of treatment, and the recommendation for when the athlete may safely return to the game (McCrea, Kelly, Kluge, Ackley, & Randolph, 1997). Research efforts have focused on the identification of the variables and corresponding assessment instruments most sensitive to the often subtle changes following concussion (e.g. Guskiewicz, Kiemann, Perrin, & Nasher, 1997; Hinton-Bayre, Geffen, & McFarland, 1997; Leininger, Gramling, Farrell, Kreutzer, & Peck, 1990; Lovell & Collins, 1998; Macciocchi, Barth, Alves, Rimel, & Jane, 1996; MacFlynn, Montgomery, Fenton, & Rutherford, 1984; Maddocks & Saling, 1996; Matser, Kessels, Lezak, Troost, & Jordan, 2000; McCrea et al., 1997). Research has also investigated the predisposing factors which increase risk of injury (e.g. Collins, Grindel, et al., 1999; Jordan, Relkin, Ravdin, Jacobs, & Gandy, 1997; Teasdale & Engberg, 1997) and the procedural methods and statistical analysis which most accurately provide valid and reliable conclusions (e.g. Daniel et al., 1999; Hinton-Bayre, Geffen, Geffen, McFarland, & Friis, 1999; Jordan, Matser, Zimmerman, & Zazula, 1996; Satz et al., 1999).

Evaluation of the short- and long-term effects of various types of concussions requires the comparison of concussed athletes with controls, or more preferably, with their own pre-injury ability. This study provides data which better illuminates the baseline of high school students on a standardized concussion assessment, a test of information processing, and a test which measures attention and reaction time. It also evaluates the effects of learning disabilities (LD), disorders of attention (i.e. Attention Deficit Hyperactivity Disorder (ADHD) or Attention Deficit Disorder (ADD)), and previous concussion on test performance. Armed with this information, athletes who are not seriously injured can return quickly and safely to the game and those who are at continued risk can be further monitored.

Concussion Research

The neurocognitive effects of sports-related brain injury have been investigated by a number of researchers with specific focus on conditions including mild uncomplicated concussion (Barth, 1998), genetic predisposition (Jordan et al., 1997), pre-existing conditions (Collins, Grindel, et al., 1999), Second Impact Syndrome (Tomecek, 1999), multiple concussion and Dementia Pugilistica (DP) (Erlanger, Kutner, Barth, & Barnes, 1999) and postconcussion syndrome (Evans, 1994). Collins, Grindel, et al. (1999) suggest that the variability in the sequelae of individual insults to the brain results from the absence or presence of these variables and the interaction of those variables present. The identification of modifiable risk factors is a significant part of a broader plan proposed by Thurman et al. (1998) which also includes the development and testing of interventions, program implementation, and outcome evaluation.

<u>Concussion Definition, Signs, and Symptoms.</u> The term "minor head injury" has historically been used to define a condition stemming from injury to the brain when in fact it can be confused with injuries such as facial wounds, a dislocated jaw, or a scalp laceration (Rutherford, 1989). In recent usage, the term "mild brain injury" has been favored and has been applied to accurately describe the type of injury incurred. Concussion is usually characterized as the least serious aspect of the mild brain injury continuum. The mild brain injuries most often incurred in sports are the acceleration-deceleration type, rotational in nature, or both (Kelly et al., 1991). Concussion is typically defined as a traumatically induced alteration in mental status with or without loss of consciousness (duration of LOC < 20 minutes), a Glasgow Coma Scale (Appendix A) score ranging from 13-15, and negative findings on neuroimaging (Rimel, Giordani, Barth, Boll, & Jane, 1981). The Glasgow Coma Scale (GCS) has been used in clinical practice to classify brain injury severity. In a study by Kraus et al. (as cited by Kraus & Nourjah, 1989), all hospital admitted brain injury residents in 1981 in San Diego were classified on the basis of the Glasgow classification system. Those with a GCS of 13-15 were termed "mild" and included about 82% of the persons hospitalized with brain injury. And while mild brain injury was the most common form of brain injury in the hospitalized population studied, many more people sustain concussions, but are not seen by a physician or taken to the hospital.

Problems in accurately identifying concussion exist because of the wide variability in presentation of signs and symptoms. Kelly and Rosenberg (1997) provide a list of observable signs and of symptoms reported both initially and later that are associated with concussion. Observable signs may include vacant stare, delayed verbal and motor responses, inability to focus attention, disorientation, slurred or incoherent speech, gross observable incoordination, emotionality out of proportion to circumstances, memory deficits and any period of loss of consciousness. Symptoms often reported early after the injury include headache, dizziness or vertigo, lack of awareness of surroundings, nausea and vomiting. Delayed symptoms may include persistent low-grade headache, lightheadedness, poor attention and concentration, memory dysfunction, easy fatigability, irritability and low frustration tolerance, visual disturbance, auditory disturbance, anxiety and mood disturbance, and sleep disturbance. Virtually any behavioral change in an athlete suspected of concussion should be taken seriously (Collins, Lovell, & McKeag, 1999).

Concussion produces diffuse damage in brain structure, often at the cellular and subcelluar level where axonal damage occurs from acceleration-deceleration type injuries (Povishock & Coberg, 1989). Problems with clinical assessment of concussion arise, therefore, because cellular damage cannot be directly observed. Injuries of this type are most often detected by postmortem inspection of the brains of animal subjects (Povishock & Coburn, 1989). The most commonly used imaging methods (e.g. magnetic resonance imaging, computed tomography) for detection of brain damage in humans may reveal a more severe injury (Levin, Williams, Eisenberg, High, & Guinto, 1992) but are typically unable to detect the subtle pathology that occurs following concussion (Collins et al., 1999). In addition, neuropsychological test batteries were developed to detect localized brain injury rather than the diffuse damage which affects information-processing speed and flexibility (Gronwall, 1989). Evidence presented by Gronwall (1989) indicates that when using the typical neuropsychological instruments, return of test scores to normal level does not necessarily imply full recovery from trauma.

The glut of early research on concussion in adults was based on assessments conducted after injury with no pre-injury data for comparison. Stuss et al. (1985) studied residual mental deficits in 20 patients who were identified as having a good recovery (according to the Glasgow outcome scale) after closed head injury, regardless of the severity. They correctly identified head injured from non-head injured patients 85% of the time using a 4 to 5 hour long neuropsychological test battery. The most striking impairment in the head injured group was in their decreased ability to perform tasks which require divided attention, while deficits in memory and information processing were also identified. The study suggested that commonly used outcome scales such as the Glasgow may not be sufficiently sensitive to identify cognitive deficits that may contribute to the subjective complaints of patients with apparently good outcome.

Concussion Awareness and Classification Strategies. The need for standardized assessment and management of concussion has been addressed by recent conferences dedicated to that topic. The Concussion in Youth Sports Conference (1998) identified brain injury as a major cause of disability in the pediatric and young adult population. Conference goals were a) to raise awareness of the incidence of acute potentially dangerous effects of head injury and the subtle but significant long term sequelae of repetitive concussion in youth, and b) to promote new guidelines for evaluation and management of concussion in youth, as well as the prevention of secondary impact brain injury.

The 17th Annual National Academy of Neuropsychology Conference (1997) also dedicated a course to the neuropsychology of sports-related concussion. This conference provided current statistics and standards in defining and treating concussion. It also provided a format for the most recent concussion studies and highlighted issues to be addressed in the future.

There are several existing guidelines which attempt to classify the severity of concussion. The Cantu Guidelines (Cantu, 1986), Colorado Guidelines (Kelly, 1991), and the Practice Parameter (American Academy of Neurology, 1997) each identify three levels of concussion (Grades I, II, and III) of increasing severity. The classifications differ in the use of "loss of consciousness" as a defining point between levels, as well as their use of terms such as "amnesia", "confusion", and "mental status" which are not clearly defined. The variation in the parameters which define the various levels are evident in Table 1 (Appendix G, page 76). There is even greater variability in the guidelines for return to play. The Colorado Guidelines (Kelly, 1991), LaBlanc Guidelines (LaBlanc, 1994), and the Practice Parameter Guidelines (American Academy of Neurology, 1997) for return to play are represented in Table 2 (Appendix G, page 77). They do not consistently address the various grades of concussion or concussion frequency. They also differ in the diagnostic and treatment recommendations made, as well as, in the length of time before an athlete can return to the game.

College and high school sports became a feasible venue for quasi- experimental research designed to measure cognitive changes which result from mild injury to the brain because athletes represent an easily defined population whose participation in a contact sport makes them more likely to incur such an injury (Barth, 1998; Harmon, 1999). Cantu (1996) estimated that as many as 250,000 concussions occur in high school football alone and LeBlanc (1994) determined that up to 20% of players sustain a concussion. In order to draw more accurate conclusions from post-injury assessment, researchers have obtained baseline (pre-injury) data on large groups of athletes using increasingly sensitive neuropsychological measures (Barth, 1998; Collins, Grindel, et al., 1999; Macciocchi et al, 1996).

Pediatric Brain Development and Injury Sequelae. The use of sensitive neuropsychological instruments in the diagnosis and treatment of concussion may be of special importance in sports injuries acquired before adulthood. Developmental issues come into play as the nature of injury and course of recovery differ at various levels of brain development. The cortex of the human brain is relatively undifferentiated at birth (Antell, 1999). Antell's description of brain development is summarized here: When compared to adults, children's brains are characterized by incomplete development, greater plasticity, and greater dependency on experience. In normal development, neurological change facilitates the development of highly specific functions that exist within different structures of the brain and communicate throughout the brain along interactive pathways. These changes result from age-related development that follows a pattern that is generally predictable, but also influenced by experiences through feedback loops. Some developmental milestones are strongly tied to critical periods, as in speech acquisition, which if missed, preclude the normal development of a specific skill.

Antell (1999) goes on to describe the result of injury to a child's brain as a disruption of the normal developmental process as summarized here: The younger the organism, the more diffuse the impact of brain injury because of its yet undifferentiated nature. While an adult may acquire an injury to a fully developed structure with subsequent discrete function loss, an insult to a single function of a child's brain will result in disruption of the interactive process of development. The brain may reorganize itself and therefore develop the functions intended for one specific region in another region or regions. While the plasticity of a child's brain allows maximal functionality, a single insult can affect the entire process of future development. Therefore, while it is fairly easy to observe the loss and recovery of basic skills acquired prior to the injury, it is extremely difficult to predict the course of skills not yet developed.

While the majority of children who sustain a mild head injury or concussion rapidly return to normal functioning, there are exceptions. Snoek (1989) studied a group of 967 consecutive patients age 2 months to 17 years who presented at the emergency room for brain injuries ranging from mild to severe. Of these, 42 children developed neurological signs after a seemingly minor injury (i.e. Forty of the children experienced no loss of consciousness, amnesia, hematoma or skull fracture while two experienced a loss of consciousness for less than 5 minutes). Thirty-nine of the children exhibited delayed deterioration after a lucid period with development of symptoms which ranged from sensory disturbance, seizure, loss of consciousness, focal neurological signs, cortical blindness, and confusion. In all but one of these cases, there was a spontaneous and full recovery within hours or days. The other three children died within 31 hours, two of whom also had a lucid period and had resumed their activities (bicycling and skateboarding) after the accident and developed symptoms hours later.

Genetic Predisposition. Recent research identifies the potential predictive value of the apolipoprotein epsilon 4 allele (APOE4) as a genetic risk factor for brain damage. While it is beyond the scope of this investigation to report the research associated with APOE4 in detail, it is included briefly as an example of a risk factor which may have future predictive value for concussion outcome estimates. APOE4 has been indicated as a contributing factor in studies investigating the severity of neurological deficits in the development of DP in boxers (Jordan et al., 1997), the severity of persistent impairment following moderate and severe head injuries (Friedman et al., 1997), the degree of brain damage following a cerebral vascular accident (McCarron, Delong, & Alberts, 1999; Slooter et al., 1997), and the development of Alzheimer's dementia in persons with Down's Syndrome (Del Bo et al., 1997). While athletes are not routinely screened for genetic markers, research of this type may contribute to the understanding of the importance of managing identifiable risks.

Pre-existing Conditions. The assessment of concussion is dependent upon the concussed athlete's ability to respond to cognitive tasks and the comparison of post-injury performance to either normative data or to their own baseline performance. While comparing a concussed athlete with group norms can be informative, comparison with the athlete's own pre-injury performance allows more conclusive evidence of altered ability, especially in those cases where a pre-concussive brain dysfunction has been identified.

Learning disabilities are neurological in origin, and can impede a person's ability to store, process, and produce information. Learning disabilities can affect one's ability to write, speak, or compute math, and can impair socialization skills (National Center for Learning Disabilities, 2000). In the United States, 15% of the population, or one in seven Americans, has some type of learning disability, according to the National Institutes of Health (cited in Coordinated Campaign for Learning Disabilities, 1998). Difficulty with basic reading and language skills are the most common learning disabilities. As many as 80% of students with learning disabilities have reading problems. Premorbid conditions such as learning disabilities may impact an athlete's performance on baseline assessment tasks and could have important implications for accurate post-injury assessment and return to game decisions as well.

The premorbid existence of learning disabilities (Collins, Grindel, et al., 1999) and cognitive dysfunction due to previous brain injury (Teasdale & Engberg, 1997) have been found to influence an athlete's performance on pretesting. Furthermore, both authors found that athletes with these pre-existing conditions demonstrated a more significant decline when concussed than athletes without these premorbid conditions. Teasdale and Engberg predict an estimated risk of 1.57 (95% confidence interval 1.32 to 1.86) for concussion in the presence of cognitive dysfunction. In addition, Gerberich et al. (1983) found that players with a prior history of loss of consciousness had a risk of loss of consciousness four times that of the player without a prior history. Studies underway by the National Football League and many college teams involve the pre-testing of all athletes, both to provide group normative statistics and to provide individual pre-test scores for post-test comparisons in the event of a concussion.

Collins, Grindel, et al. (1999) found evidence that athletes with pre-existing learning disabilities may be at increased risk of sustaining significant injury as a result of a concussion when they examined the relationship between concussion, premorbid learning disabilities (LD), and neuropsychological performance in college football players. In their study of 393 athletes from four university football programs, multivariate analysis of variance yielded significant main effects for both LD (P=.001) and concussion history (P=.009) resulting in lower baseline performance on neuropsychological evaluation. They also identified a significant interaction between LD and history of multiple concussions on two of the neuropsychological measures; Trail-Making Test, Form B (P=.007) and Symbol Digit Modalities Test (P=.009). Findings indicate poorer performance for the group with LD and multiple concussions compared to other groups.

Deficits in attention also may effect scores on instruments used as baseline measurements in athletes. Attention Deficit Disorder (ADD) and Attention Deficit Hyperactivity Disorder (ADHD) are believed to be neurological in nature. In the interest of ease in communication, the term ADHD will be used to refer to both ADD and ADHD, though they do differ according to whether or not hyperactive behavior is present. According to the Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (DSM-IV; American Psychiatric Association, 1994), ADHD is defined as a persistent pattern of inattention and/or hyperactivity-impulsivity that is more frequent and severe than is typically observed in individuals at a comparable level of development. The symptoms must have been present before 7 years of age, impairment from the symptoms must be present in at least two settings, and there must be clear evidence of interference with developmentally appropriate social, academic, or occupational functioning. It must not occur exclusively during the course of another mental disorder and must not be better accounted for by another mental disorder. Diagnosis of the disorder requires that the child exhibit at least six or more of the defining symptoms at a frequency which occurs "often" when compared to other normal children.

However, the atheoretical description of the disorder as in the DSM-IV, which holds that the subtypes of ADHD are identical in regard to attentional deficits and differ only in the presence of hyperactive-impulsive symptoms is insufficient (Barkley, 1994). According to Barkley, the processes which contribute to ADHD include a) deficits in inhibitory processes, b) disruption of the development and performance of self-regulation, c) deficits in those executive functions which contribute to self-regulation, and d) deficits in motor control. His description of ADHD is summarized here: ADHD is a disorder which disrupts the temporal relationship between thought and action, knowledge and performance, past and future from the moment, and time from the rest of the three dimensional world. It is a disorder of performance more than a disorder of skill as it dissociates crystallized intelligence from its application in the real world. The DSM-IV, reports the prevalence of ADHD as estimated at 3 to 5 % in school age children with limited data on the prevalence in adolescence and adulthood. However, Lambert, Sandoval, and Sassone (as cited in Barkley, 1998) suggest that the incidence is significantly dependent on the way ADHD is defined and measured, the population studied, the geographic locale of the survey, and the degree of agreement required between parents, teachers, and professionals. Despite these discrepancies, ADHD is included as a possible risk factor for concussion because of the biological nature of the disorder, and the behavioral components of impulsivity and poor attention which are often associated with brain injury acquisition.

Second-Impact Syndrome. Animal studies have indicated that the brain is more vulnerable immediately following a head injury, and during this time is more susceptible to additional injury (Hovda, 1998). Diffuse cerebral swelling with catastrophic deterioration is a known complication of human brain trauma and has been hypothetically associated with repeated brain injury in sports (McCrory & Berkovic, 1998). These concerns are central to the quest to develop guidelines in sports that attempt to predict when it is safe for an athlete to return to play after a suspected concussion.

The most serious risk in premature return to play is the possibility of Second Impact Syndrome (SIS) (Harmon, 1999). SIS is a condition which is marked by the development of catastrophic diffuse cerebral swelling in an individual who, after having sustained an initial head injury, most often a concussion, sustains a second head injury (even if mild) before symptoms associated with the first have fully cleared (Tomecek, 1999). While rare, SIS results in swelling and bleeding in the brain associated with high mortality and very high rates of severe disability. Upon onset of the second concussion, brain stem failure usually occurs in 2 to 5 minutes. Even a minor blow to the chest, side or back following an unresolved concussion can result in rapid, irreversible, brain swelling which often leads to death or severe brain damage (Cantu & Voy, 1995). While statistics on the occurrence of SIS are incomplete, the Center for Disease Control (1997) identified 17 cases between 1992-1995. The majority were male adolescents or young adults who suffered a fatal or catastrophic second concussion while participated in boxing, football, ice hockey, or snow skiing.

The incidence of SIS is not well documented in adult research. Tomecek (1999) identifies childhood and adolescence as risk factors for SIS along with contact sports. He theorized that due to the still evolving physical and neurological development of children, they are more vulnerable to the physiologic effects of mild head trauma, and their risk of SIS is possibly higher than that of older athlete because their recovery period may be longer.

McCrory and Berkovic (1998), however, question the legitimacy of SIS as a diagnosis. They conducted an analysis based on their criteria for the classifications of SIS as definite, probable, possible, and negative in 17 published cases. Each classification consisted of a combination of the following four criteria: a) medical review after a witnessed first impact, b) documentation of ongoing symptoms following the first impact up to the time of the second impact, c) witnessed second head impact with subsequent rapid cerebral deterioration, and d) neuropathologic or neuroimaging evidence of cerebral swelling without significant intracranial hematoma or other cause for edema. Definite SIS consisted of criterion a,b,c, and d. Probable SIS consisted of criterion c and d plus either a or b. Possible SIS consisted of c and d only. Negative SIS consisted of absence of c or d. Based on this classification system, they found only five cases of probable SIS and the remaining 12 were not SIS. While a criterion based classification system is nosologically appealing, the system used by these authors is arbitrary, quite conservative, and provides no greater empirical fortitude than inclusion based on the descriptions used previously. Additionally, the threat of Type II error, given the gravity of the implications of SIS, should preclude dismissing the prevention of SIS as a goal for guideline development.

The risk of SIS may be reduced when the symptoms of concussion are recognized and treated and recommendations for return to play are based on medical advice (Tomecek, 1999). In 1994, Saunders and Harbaugh recommended the use of computed tomography to rule out cerebral contusion before permission to return to play is granted. Since that time, a number of concussion severity scales and return to play guidelines have been proposed which provide simple and inexpensive assessment and are the basis of subsequent recommendations (e.g. Cantu, 1986; Practice Parameter, 1997).

Multiple Concussions and Dementia Pugilistica. While concussion is typically the result of a single event that results in altered mental status, some athletes develop symptomology as a result of repeated subconcussive blows to the head. The development of Dementia Pugilitica (DP) in boxers reflects the effects of numerous subconcussive blows to the head with exacerbation by identifiable concussions sustained. DP is characterized by the manifestation of early symptoms of mild confusion and ataxia, with progression to a "Parkinsonian" pattern of cognitive decline, impaired performance on memory tests, increased motor and speech latencies, pyramidal tract dysfunction, tremor in the head and upper extremities, and behavioral changes. The severity of DP in boxing exists along a continuum with an approximately 20% prevalence of moderate to severe impairment, with increased risk associated with certain genetic factors and the number and severity of concussions incurred (Erlanger et al., 1999). Erlanger et al. proposed neuropsychological assessment as the most sensitive method for early detection of DP, and promoted the use of serial testing of boxers' cognitive functioning for early signs of neurologic dysfunction and in decision making regarding the athlete's health and career goals.

Athletes who engage in soccer also sustain similar multiple subconcussive blows from contact between the head and the soccer ball in a move called a "header" where the athlete uses his or her head to deliberately divert the ball. A review of the literature regarding brain injury in soccer by Baroff (1998) found inconclusive evidence that "heading" was related to brain injury. He encouraged clarification of the risk through more definitive studies. A study published that same year by Matser, Kessels, Jordan, Lezak and Troost (1998) found that performance on neuropsychological tests of planning, memory, and visuospatial processing was significantly poorer in soccer players than in controls. They also found that neuropsychological test performance on these tests was inversely related to the number of concussions in soccer and the frequency of heading the ball.

In a subsequent study, Matser, Kessels, Lezak, Jordan and Troost (1999) found that amateur soccer players with a mean amateur career of 17 years exhibited impaired performance on tests of planning and memory when compared to control athletes. Athletes from three complete soccer teams (N = 33) were compared with 27 control athletes from two middle distance track teams and one middle distance swimming team. Athletes with any condition that might affect cognitive function were excluded. The study found that 7% of controls versus 27% of amateur soccer players ($p = .004$) showed moderately to severely impaired scores on the figural memory test (Complex Figure Test

Immediate Recall). Thirteen percent of controls versus 39% of amateur soccer players ($p = .001$) showed moderately to severely impaired scores on the test of planning (Wisconsin Card Sorting Test). In addition, they found an inverse relationship between the number of concussions and neuropsychological performance on 6 of the 27 neuropsychological tests administered in those athletes who had sustained a concussion. The deficits were evident in tests of memory and planning.

Postconcussion Syndrome. Mild head trauma is often complicated by a persistent set of symptoms known as postconcussion syndrome (PCS) (Ferguson, Mittenberg, Barone, & Schneider, 1999). PCS refers to signs and symptoms which do not quickly resolve or those which present after a delay following a concussion. Evans (1994) provides a list of signs and symptoms which include headache, dizziness, vertigo, tinnitus, hearing loss, blurred vision, diplopia, convergence insufficiency, light and noise sensitivity, diminished taste and smell, irritability, anxiety, depression, personality change, fatigue, sleep disturbance, decreased libido, decreased appetite, memory dysfunction, impaired concentration and attention, slowing of reaction time, and slowing of information processing speed.

There has been much debate about the etiology of those symptoms which persist after concussion, with focus on the psychological, emotional and legal aspects of injury maintenance (Evans, 1994). Ferguson et al. (1999) studied the effects of expectation on the experience of PCS following sports-related head injury in 209 males involved in high school, collegiate, and postgraduate collision sports. When they compared head injured athletes' premorbid subjective symptom rate with their estimated increase in postconcussion symptoms, they found that 97% underestimated their pre-injury symptom rate in a manner consistent with their symptom expectations. They suggest that uninjured athletes believe that concussion would produce persisting symptoms and that concussed athletes attribute symptoms to the concussion when in fact the symptom rate is consistent with non-injured athletes.

Assessment Instruments and Functions Sensitive to Concussion. The measure of when concussed players are "recovered" has been defined as a return to preseason performance on neuropsychological testing. Recent research has attempted to identify those tests which best differentiate both immediate and long term cognitive and behavioral deficits following concussion. Neuropsychological test batteries and sideline assessment instruments such as the Standardized Assessment of Concussion (SAC) (McCrea, Kelly, Kluge, Ackley, & Randolph, 1997) have included those functions which are believed impacted by concussion including orientation, concentration, memory, and attention (Colorado Medical Society, 1991; Practice Parameter, 1997). McCrea et al. (1998) found that the SAC total score, Immediate Memory, and Delayed Recall demonstrated significant group differences between mildly concussed and nonconcussed players and between mildly concussed players' own pre- and post-injury performance with concentration scores approaching significance. A later study of 568 high school and college football players by McCrea et al. (1998) found significant pre- and post-concussion differences on the measures of Orientation, Memory, Concentration, Delayed Recall, and on the Total score of the SAC. Research using the SAC has thus far indicated that the mental status tests it employs typically indicate return to normal levels within 48 hours, while other psychometric tests indicate impairment extending up to weeks (Hinton-Bayre et al., 1999).

Barth (1998) assessed 2,350 college football players prior to the season. Cognitive assessments were then conducted on those athletes who suffered mild concussion and on appropriate control subjects at 24 hours, 5 days, and 10 days. Results revealed statistically significant, though subtle, reductions in head-injured athletes' ability to attend and solve new problems rapidly. They also showed a significant increase in headaches, memory problems, and dizziness. The symptoms remitted rapidly and the athletes returned to pre-season abilities within 5 to 10 days after their injuries.

Consistent with these findings, Macciocchi et al. (1996) found that college athletes experienced a rapid recovery from concussive symptoms and were able to return to play in less than 10 days. In the Macciocchi et al. study, a large sample (n = 2300) of collegiate football players and controls were assessed using the Paced Auditory Serial Attention Test (PASAT), the Digit Symbol Test, the Trail Making Test, and a symptom checklist before the game and at 24 hours, 5 days, and 10 days after injury. Players with head injuries reported a greater number of symptoms and displayed impaired performance when compared to controls, though the impairment resolved within 5 days for most players. Significant improvement between 24 hours and 5 days, as well as between 5 days and 10 days was evident in the players with concussion. The authors concluded that simple, uncomplicated mild head injuries do cause limited neuropsychological impairment that generally resolves rapidly with minimal prolonged sequelae.

In contrast to reports of rapid and complete recovery, Hinton-Bayre et al. (1999) found evidence that three psychometric tests of information processing (Speed of Comprehension, Digit Symbol, and Symbol Digit) were sensitive to the effects of concussion beyond 5 days. They concluded from this study (described later) that the instruments used and the analysis conducted impact the ability to detect the often subtle deficits present after concussion (Hinton-Bayre et al., 1999). When using a Reliable Change Index to identify individual differences, 16 out of 20 concussed players showed significant impairment on at least one of the tests at 1 to 3 days, and 9 out of 20 continued to perform significantly below baseline on at least one test at 1 to 2 weeks post-injury. They add that while all the concussed players were not tested twice preseason, the number may be underestimated due to the shown practice effect of the double preseason testing. They concluded that obtaining a double baseline preseason helps to minimize the effects of practice on the change in performance before and after injury, but that practice effects may continue to mask continued deficits in some tests.

In a group analysis, while the two groups did not differ pre-season, they found a significant difference between concussed and nonconcussed athletes when tested at specified intervals. The concussed players performed worse at 1 to 3 days, but improved to preseason levels at 1 to 2 weeks post-injury. They suggested that the Speed of Comprehension test, which was the most sensitive of the three, was not sufficiently sensitive to measure impaired performance. In conclusion, recovery rate variability between studies suggests important differences in the number of brain functions being assessed, the instruments used to assess them and the practice effects of repeated measures (Hinton-Bayre et al., 1999).

Crawford, Johnson, Mychalkiw, and Moore (1997) studied the use of Wechsler Adult Intelligence Scale - Revised (WAIS-R) summary IQs, factor scores, and subtest scatter indices in identifying deficits after head injury. They found that the Attention/Concentration factor and those tests which make it up (Digit Span, Digit Symbol, and Arithmetic) yielded the greatest differences between the head injured group and controls, a finding consistent with Lezak's clinical observations (as cited in Crawford et al., 1997) that these three tests are most likely to expose problems following head injury.

The use of computerized complex reaction time (RT) - based neuropsychological procedures has provided evidence of persisting impairment following concussion, even when performance on traditional neuropsychological measures was in the normal range (Bleiberg, Halpern, Reeves, & Daniel, 1998). Hugenholtz, Stuss, Stethem and Richard (1988) studied 22 adults with mild concussion diagnosed with strict criterion to distinguish them from other types of minor head trauma. The participants were tested five times during the first 3 months following the injury using a neuropsychological reaction time test of simple and choice reaction time. The concussed subjects exhibited significant attentional and information processing impairment on the choice reaction time test with the greatest difference evident in the first month and failure to attain the skill of the control group even after 3 months. These findings were evident even in the absence of any apparent neurological problems, suggesting an extended recovery process for some skills not typically assessed. When compared with nonconcussed matched controls on the simple reaction time test, the concussed group was approximately 28 ms slower on the average, though this difference between groups was not statistically significant. The lack of significance on the simple reaction time test may suggest that the higher level information processing component of choice (as opposed to simple) reaction time tests may be more sensitive to concussion effects. Hugenholtz, Stuss, Stethem and Richard also found that the 7 concussed subjects in their study who had experienced a previous concussion, when compared to the 15 with no previous concussion, were 17 to 65 ms slower on the choice reaction time tests during all five visits, though the trend was not significant.

Cremona-Meteyard and Geffen (1994) found that when compared to matched control athletes, concussed football players continued to display selective attention deficits 1 year after injury. They exhibited a reduced ability to benefit from valid cueing on a cued reaction time test of visuospatial attention, though their performance on a task that measured the RT cost of miscuing did not significantly differ from controls. The authors suggest that a persistent consequence of concussion may be the inability to take action quickly in response to expected events.

Maddocks and Saling (1996) detected neuropsychological deficits after resolution of neurological symptoms in 10 concussed football players at 5 days post injury. Baseline data was collected on 130 players using the Paced Auditory Serial Addition Test (PASAT), Digit Symbol Substitution Test (DSST), and Four-Choice Reaction Time, involving measures of decision time (DT) and movement time (MT). No differences were evident on baseline measures between players with a past history of concussion, players with no history of concussions and the control group. Using pre-test measures as covariates in an analysis of variance, the concussed players demonstrated significantly slower performance on the DSST ($F(1,16) = 0.15$, $p = 0.04$) and slower initiation of responses on the DT ($F(1,16) = 7.61$, $p = .01$) following concussion when compared with nonconcussed age-matched umpires. Performance between groups did not differ on the PASAT or the MT.

The Standardized Assessment of Concussion (SAC) (McCrea et al., 1997) was the first instrument specifically designed with the intention of quantifiably measuring the immediate neurocognitive effects of concussion. The SAC was developed as a sideline instrument tool for use by athletic trainers, physicians and other personnel faced with the responsibility of detecting concussion in athletes immediately after the injury and making decisions as to a player's readiness to return to play. The SAC was found to be sensitive to changes which occur as a result of concussion. When examinations of concussed players were compared with their own baseline performance and to nonconcussed controls, they were found to have significantly lower scores (McCrea et al., 1998).

Data Analysis. Comparison of an individual's baseline data with post-concussion scores may be confounded by practice effects (Macciocchi et al., 1996; Maddocks and Saling, 1996), thereby making group comparisons of functional impairment and recovery after injury unreliable. Hinton-Bayre et al. (1999) endorse the use of a Reliable Change Index (RCI) which allows comparisons between different tests, players, and repeated measures. Group analysis obscured the effects of concussion when compared with RCI analysis on the information processing tests Digit Symbol, Symbol Digit, and Speed of

Comprehension. Individual changes following concussion were found in 16 of the 20 concussed professional rugby league players at 1 to 3 days post-concussion with seven players still impaired at 1 to 2 weeks.

Summary and Goals of this Study.

In summary, the effects of mild brain injury or concussion on neurocognitive functioning has been well documented (Collins, Grindel, et al., 1999; Cremona-Meteyard & Geffen, 1994; Dikmen, McLean, & Temkin, 1986, Erlanger et al., 1999; Hovda, 1998). While initial results indicate that deficits generally resolve within 5 to 10 days (Barth, 1998; Macciocchi, et al., 1996) more sensitive instruments and more reliable data analysis may demonstrate the recovery curve more accurately (Hinton-Bayre et al.,1999; Hugenholtz et al.,1988). Players who have a history of learning disabilities or multiple concussions perform more poorly than other groups on baseline data (Collins, Grindel, et al., 1999; Teasdale & Engberg, 1997). It is suggested that those athletes with a premorbid history of learning disabilities, ADHD, or previous concussion fair less well than others when concussed.

The goals of the current study are 1) to demonstrate the validity of the SAC, the CPT, and Digit Symbol in assessing the residual deficits from concussion, 2) to identify the individual and collective effects of learning disabilities, ADHD, and previous concussion on baseline test data. It is hypothesized that premorbid neurological conditions and previous concussion history will be associated with lower scores on the SAC, CPT, and Digit Symbol, and that participants who have both of these conditions will perform more poorly than any other group.

Method

Participants

Participants in this study consisted of male junior-high and high school athletes from the Oklahoma Public School System schools; Kingfisher, Piedmont and Putnam City. Participants from the Kingfisher and Piedmont schools were assessed during the latter part of the regular school year, 2000-2001. Two additional participants from Piedmont and all the Putnam City participants were summer 2001 school students. The participants were in the eighth through twelfth grades during the 2000-2001 school year.

Of the 106 participants who completed the assessment, 73.6% were Caucasian (n=78), 10.4% were African American (n=11), 3.8% were Native American (n=4), 0.9% were Asian (n=1), 2.8% were Hispanic (n=3), and 0.9% indicated "other" (n=1). Eight (7.5%) participants did not indicate ethnicity.

Three (2.8%) of the participants were in the eighth grade, 29 (27.4%) in the ninth grade, 34 (32.1%) in the tenth grade, 31 (29.2%) in the eleventh grade, and 9(8.5%) in the twelfth grade. The participant's mean age was 16.28 with a range of 14 to 19. The participant's ages were as follows; 3 (2.8%) were 14 years old, 28 (26.4%) were 15, 31 (29.2%) were 16, 26 (24.5%) were 17, 16 (15.1%) were 18, and 2 (1.9%) were 19.

Twenty-eight (26.4%) participants were from Kingfisher High School, 51(48.1%) from Piedmont High School, and 27 (25.5%) from Putnam City High School. The average grade point average was 2.6 with a range of 0 to 4.0. (GPA was calculated based on the participant's report of grades earned over the past two years; Mostly A's = 4.0, A's and B's = 3.5, mostly B's = 3.0, B's and C's = 2.5, mostly C's = 2.0, C's and D's = 1.5, mostly D's = 1.0, D's and

F's = .5, and mostly F's = 0. One participant reported making mostly F's which translated to a zero on the scale used).

Instruments

Standardized Assessment of Concussion. The SAC (McCrea et al., 1997) is a brief standardized instrument designed to assess functions sensitive to concussion as indicated by the American Association of Neurology Practice Parameter and the Colorado Guidelines for the assessment of concussion. The four components and possible points for each are as follows: Orientation = 5 points, Immediate Memory = 15 points, Concentration = 5 points, and Delayed Recall = 5 points. The maximum total score on the SAC is 30 points. The SAC requires approximately 5-7 minutes to administer and is designed so that medical personal, coaches, trainers or other persons can be trained in its use, with no need for previous expertise in psychometric testing. Alternate Forms A, B and C of the SAC were designed to allow follow-up testing of injured players with minimal practice effects in order to track postconcussion recovery. The three forms differ only in the stimulus selection of digits in the Concentration section and words used to test Immediate Memory and Delayed Recall. Initial studies indicate there are no systematic differences in the three forms of the test, nor in the administration of the test during games versus during practice as indicated by one way ANOVAS. There were no differences in the administration or scoring among three participating athletic trainers. There was also no significant correlation between total score and age. The SAC is printed on a pocket-sized card for convenient use on the sideline.

Orientation is assessed on the SAC by requesting the athlete to provide the day of the week, month, date, year and time of day within 1 hour (one point for each correct answer). The Immediate Memory subtest consists of a five-item word list; the list is read to the subject for immediate recall, and the procedure is repeated for three trials (one point for each word recalled during three trials). Concentration is tested in two parts: the subject repeats, in reverse order, strings of digits that increase in length from three to six numbers and they recite the months of the year in reverse order (one point for each string of digits correctly recalled in reverse order and one point for recitation of months in reverse order with no errors). Delayed Recall of the original five-word list is also assessed (one point for each word recalled).

The SAC is designed to be administered immediately following injury at rest with the last component (Delayed Recall) administered after some exertion exercises. The AAN and Colorado Guidelines recommend the exertion component to create conditions of increased intracranial pressure under which postconcussive symptoms such as headache, nausea and dizziness are most likely to be observed or reported. The exertion exercises are not scored and consist of 5 knee bends, 5 sit ups, 5 push ups, and 5 jumping jacks. The SAC Total Score is a summation of the four subtests and is computed in order to derive a composite index of the subject's overall level of impairment following concussion. If the total score is less than or equal to 24, the injury is characterized as a concussion. A neurological screening which consists of strength, coordination, sensation, and orientation components is also conducted, but not scored.

In the initial study by McCrea et al.(1997), the SAC was able to discriminate between concussed and non-concussed players immediately after the injury ($F(1,145) = 18.4$, $p \leq 0.0001$) with the concussed group's mean score falling 1.84 standard deviations below the control group's mean.

A later study by McCrea et al. (1998) with a larger sample size found "marginally" significant differences between the three forms ($F(1,568) = 3.2$; $p \leq .04$.) Though the test is relatively simple, the ceiling effect was not considered problematic as the average score for normal participants was 1.60 standard deviations below the ceiling. Of the 568 athletes administered the test, 7% achieved a perfect score. During the course of the study, 33 athletes sustained a concussion. A matched paired t-test indicated significant differences between concussed players pretest and post-test scores on the SAC total score ($t = 4.6$; $p \leq .0001$). Similarly, matched paired t-tests for concussed players were significant on three of the four subtests when compared to their own pretest scores; Orientation ($t = 2.7$; $p \leq .01$), Immediate memory ($t = 4.6$; $p \leq .0001$), and Concentration ($t = 2.4$: $p \leq .02$).

When comparing concussed players (N = 33) with normal controls (N = 568), concussed players scores were significantly lower than controls on the SAC total score and on all four subtests ($p \leq .001$). Means and standard deviations for normal controls and concussed players are listed as follows, each set of scores listed respectively; Total score = 22.88(3.14) and 26.58(2.23), Orientation subtest = 4.30(1.24) and 4.82(.43), Immediate Memory subtest = 13.03(1.81) and14.51(.98), Concentration subtest = 2.64(1.06) and 3.40(1.27), and Delayed Recall subtest = 2.91(1.28) and 3.84(1.11).

<u>Conner's Continuous Performance Test - II.</u> The Conners' Continuous Performance Test - II (CPT-II) (Conners,1995) is a computer based program which provides a variety of measures designed to provide a description of a

person's sustained attention, reaction time, impulsivity, and visual discrimination. The Connor's CPT-II utilizes a unique CPT mode called "Standard". In this mode, the respondent presses the space bar or mouse button for any letter except the letter "X". There are six blocks, with three sub-blocks each of 20 trials (consisting of both target and non-target letters). For each block, the sub-blocks have different inter-stimulus intervals (ISIs) of 1, 2, or 4 seconds. The order of the ISIs varies between blocks. Each letter is displayed for 250 milliseconds. This paradigm is the default program and takes approximately 14 minutes to complete. The Connor's CPT-II provides data on a variety of measures. Omission errors reflect the number of stimuli to which the participant fails to respond. Commission errors reflect the number of times the participant erroneously responds to the letter "X". There are two reaction time measurements; one that measures the speed of the participant's responses and another that evaluates the variation of reaction time across trials or blocks. For this study, the CPT-II was loaded on a Toshiba Satellite 1755 laptop computer for portability.

Digit Symbol. Information processing speed was assessed using the Digit Symbol subtest of the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) (Wechsler, 1997). Digit Symbol is a timed task that requires one to copy symbols from a model at the top of the page into the corresponding boxes below. Each of the nine symbols is paired with one numeral from 1 through 9 on the model and the task requires copying the correct symbols into empty boxes according to which numeral is directly above it. The empty rows of boxes are filled one after another going from left to right on each row. The time limit is 2 minutes

Concussion History. The incidence of previous concussion was assessed on the Concussion History form (Appendix B) that lists signs and symptoms one may experience following a concussion. The participant indicates whether each of the listed signs or symptoms was present for less than 15 minutes, more than 15 minutes or not at all. The participant completed a separate Concussion History form for each concussion recalled. Determining the grade of each concussion was accomplished by the researcher and followed the American Academy of Neurology guidelines (Practice parameter, 1997). It is a classification tool which divides concussion severity into three grades with increasing severity. Grade 1 concussion is characterized by a) no loss of consciousness, b) temporary confusion, and c) concussive symptoms or mental status impairment with duration of less than 15 minutes. Grade 2 concussion is characterized by a) no loss of consciousness, b) temporary confusion, and c) concussive symptoms or mental status impairment with duration of greater than 15 minutes. Grade 3 concussion is characterized by loss of consciousness for any period, brief or prolonged. The concussion history form was designed to be completed by the athlete, the athlete's parent or guardian, or both.

Demographic Information. The Demographic Information form (Appendix C) was used to provide basic descriptive information including name, date of birth, age, gender, grade in school, and ethnicity. A brief school history was used to gather academic information including grades, presence of learning disability, presence of ADHD, grade retention, academic strengths and weaknesses, suspensions or expulsions, and performance on standardized tests. Permission to acquire school records was requested for validation and additional information.

Academic and Medical History. An Academic and Medical History form (Appendix D) was used to record data related to early development, significant childhood illness and injury, medications used, previous head injury, LOC, chronic conditions, nicotine, drug and alcohol use, and others. This form was designed to be completed by the participant's parent or guardian.

Conner's Parent Rating Scale - Revised Short Version (CPRS-R:S). The CPRS-R:S (Conner's, 1995) was completed by the parent or guardian of the participating athlete. The CPRS-R:S is a behavioral rating scale which lists behaviors and asks the parent to respond on a 4 choice likert type rating scale (0 = not true at all (never, seldom), 1 = just a little true (occasionally), 2 = pretty much true (often, quite a bit), and 3 = very much true (very often, very frequently)) to indicate which rating best reflects their assessment of the participant's behavior. The rating scale produces scores on four indices; Oppositional, Cognitive Problems/Inattention, Hyperactivity, and ADHD Index.

NeuroBehavioral Symptom Checklist (NBSC). The NBSC (Ozolins, Parsons, Ozolins, & Hunter, 1996) lists neurological and emotional symptoms on a 5 point likert scale ranging from 0 to 4 (0 = never, 1 = seldom, 2 = sometimes, 3 = often, 4 = very often). One checklist is completed by the participant and a separate checklist is completed by the participant's parent or guardian. The participant circles the number that best describes how frequently they have been bothered during the past month by each symptom presented. On a separate form, the participant's parent circles the number which describes how frequently they observed each symptom in the athlete during the last month. The NBSC is scored by assigning one point to each item that the participant responds with a "3" or "4" and summing the total score. The participant and parent versions are scored in the same way.

Procedure

Participation was offered to all junior high and high school male athletes in two independent school districts and to all junior high and high school male athletes taking a summer school course at a multi-school district summer school program. Approximately 130 male student athletes from the Kingfisher and Piedmont schools were provided information about the study and given the opportunity of participate. Of these, 88 expressed interest in participating, were given the parent packet, and were given the opportunity to sign up. Nine athletes did not complete the testing after getting consent and having scheduled times to participate. Seventy-nine athletes secured consent and completed the assessment. The rate of agreement to participate was low for students with LD or ADHD (N = 7). At the Putnam City Summer School, 178 potential students were screened for neurological condition. Of the 32 students who qualified, 27 secured consent and completed the assessment. The other 5 either elected to decline or were unable to secure the consent of a parent. This reflects the fact that all the students who actually underwent the assessment reported a diagnosis of either ADHD, ADD, or LD. Athletes were advised of the opportunity to participate in research. Those interested took a packet home to their parent or guardian and signed up for a testing time. Consent forms (Appendix E) for participation and for release of school records were signed by the participants and their parent or guardian. Along with the consent, a medical history form, the NBSC, and Conner's Rating Scale

(CPRS-R:S) were completed by each participant's parent or guardian and the packet was returned to the school by the participant. Testing was conducted in one of several quiet rooms with mild background noise and very limited interruption (an unused classroom, the coaches' office, or the school library). At the time of testing, the parent/guardian packets were collected and the participant began at one of three testing stations; a) CPT-II, b) SAC and Digit Symbol, and c) Paperwork. The order of testing was counterbalanced. There was a designated area for each station with enough space between them to produce minimal distraction in the event that more than one participant would be completing the assessment at the same time.

The CPT-II was set up facing a wall or corner to limit distractions. The participants were given the option to use either the mouse or space bar and were instructed to use their dominant hand. Instructions were read to the participant and repeated until it was evident they were understood. The participant was directly observed accurately responding to the CPT-II until at least one target stimulus (X) was presented on the screen. The participant was subsequently observed unobtrusively and intermittently from behind or from the side. There were no instances where the participant appeared to not understand the task. There were two instances when a participant was spoken to by another student or teacher, and three times when a participant asked a question during the CPT-II which was unrelated to the task at hand. In each of these instances, the participant was immediately redirected and there appeared to be no significant loss of data as the participants continued to respond to the computer stimuli.

The SAC and Digit Symbol were administered by the experimenter in another area at a desk or table where space also was available for the neurological screening and exertion activities to be conducted. The SAC was administered according to the instrument instructions and in the recommended sequence; orientation, immediate memory, neurological screening, attention and concentration, exertion exercises, and delayed recall. The Digit Symbol was administered according to WAIS-III (Wechsler, 1997) instructions. The participant used a pencil with no eraser and was timed using a digital timer.

The third station was simply a table or desk situated away from the other two where the participant could complete the paperwork. Participants were given instructions for each form and allowed to ask questions about items on the paperwork as needed. An assent form, demographic information form, NBSC, and concussion history form were completed by each participant at the paperwork station. A separate concussion history form was completed for each reported concussion.

Following completion of all materials, any additional questions about the paperwork were allowed and any uncompleted items were completed or put back in the envelope for the participant to return to the parent. The concussion assessment forms were reviewed by the experimenter with the participant providing necessary information.

On one of the forms in the parent/guardian packet, the parent/guardian was asked to indicate whether or not they agreed to be telephoned, if it was necessary to do so. Those who agreed to be contacted provided their phone number and the time of day they preferred to be contacted. Follow up phone interviews were conducted with the parent or guardian to clarify information or to gather additional information as needed. There were three CPRS-R:S forms completed over the phone with the parent because they were not completed with the other materials and there was no opportunity to have the student return with them. One parent called the experimenter to provide additional information about the participant's medical history. Behavioral observations were made throughout the testing, and any unusual responses were recorded. All participants were treated in accordance with the ethical standards established by the American Psychological Association. The Institutional Review Board-Norman Campus reviewed this study and approved the use of human participants in this research (Appendix F).

Design and Analysis

The proposed design was a two-factor model with three levels of the concussion variable and three levels of the neurological variable creating a 3x 3 factorial design. The proposed levels of the concussion variable were: 1) no concussion, 2) one concussion, and 3) two or more concussions. The proposed levels of the neurological variable were: 1) no neurological condition, 2) LD diagnosis, and 3) ADD or ADHD. Due to small cell sizes, the cells were collapsed to create two levels of the concussion variable: 1) no concussion and 2) one or more concussion(s), and two levels of the neurological variable: 1) no neurological condition and 2) LD, ADD/ADHD, or both. The design and number of participants are presented in Table 3 (Appendix G, page 79) provides the design and number of participants who comprised each group.

The resulting design is a two-factor model with two levels of the neurological condition variable and two levels of the concussion variable creating a two by two (2 x 2) factorial design. The neurological function variable included two levels (0= no identified learning or attentional problem and 1= LD/ADD/ADHD) and two levels of concussion (0= no previous concussion, 1 = one or more previous concussions). The dependent variables were the SAC Total Score, Digit Symbol, and CPT-Reaction Time. The Sum of Squares and Mean Squares were computed for row effects and for column effects in a Multiple Analysis of Variance (MANOVA).

The MANOVA was used to test for the effects of neurological condition and concussion history on the three primary neuropsychological test scores; the SAC Total Score, Digit Symbol, and the CPT Reaction Time. The interaction of premorbid condition and concussion history was also assessed. Univariate F tests were conducted to identify which measures accounted for any significant findings in the analysis of variance.

Results

All of the 106 participants played sports, either contact, non-contact, or both. Contact sports included those sports in which contact with other players was a necessary part of the game (e.g. wrestling, football, boxing). Soccer was also classified as a contact sport because of the frequent contact of the ball with the head as part of normal play and the literature which suggests that heading the ball is negatively correlated with cognitive function in professional players (Matser, Kessels, Jordan, Lezak, & Troost, 1998; Matser, Kessels, Lezak, Jordan, & Troost, 1999). According to the athletes' reports, the average number of contact sports played by each participant was 1.61 (range 0-3), and the average number of non-contact sports played by each participant was 1.70 (range 0-5). The number of years playing contact sports was calculated by summing the number of years for each contact sport reported played. For example, a participant who played football for three years and soccer for four years would have a total of seven years playing contact sports. The average number of years playing contact sports for each participant was 6.96 years (range 0-22).

Of all participants who responded to the question, 14.6% reported having had a tutor, 11.9 % reported having been expelled from school at least one time, 34% reported having received probation from sports because of low grades, and 59% reported having had in-school or out-of-school suspension at least one time.

The prevalence of LD within the total sample of 106 participants was 12.3% (n=13). ADD/ADHD was reported by 16.% (n=17), and 3.8% (n=4) reported a dual diagnosis of both LD and ADD/ADHD. The reports of LD and

ADD/ADHD provided by the participants were also reported by the parents of the athletes in 95% of the cases. In those with discrepancies, the parent was interviewed over the telephone to confirm the accurate history of these diagnoses.

The prevalence of at least one concussion within the total sample of 106 participants was 67% (n=71). Thirty-three percent (n=35) of the participants reported no history of concussion, 37.7% (n=40) reported having one concussion, and 29.2% (n= 31) reported having two or more concussions. There was a positive correlation between the yes/no reports of concussion by the participants and those reported by the parents/guardians (r = .470, p < .00). The reports of the number of concussions by the participants was generally higher than that reported by the parent. This is most likely due to the definition of concussion used in this study, based on current literature, that is more inclusive and does not require loss of consciousness. In the case of discrepancies, the parent or guardian was called to confirm the accurate occurrence of concussion. In some cases the participants reported a concussion which occurred in practice, during play, or at some other time which was not reported to the parent. The concussions were counted as legitimate if the participant could provide a description of the incident and the short term and any long term effects of the injury.

Of the 13 athletes with LD, 30.8% (n=4) had no history of concussion, 46.2% (n=6) had one concussion, and 23.1% (n= 3) had two or more concussions. Of the 17 athletes with ADD/ADHD, 35.3% (n=6) had no concussion, 41.2% (n=7) had one concussion, and 23.5% (n=4) had two or more concussions. Of the 4 athletes with both LD and ADD/ADHD, 75% (n=3) had one concussion and 25% (n=1) had two or more concussions.

Of the 35 athletes with no concussions, 71.4% (n=25) reported no neurological diagnosis, 11.4% (n=4) reported LD, 17.1% (n=6) reported ADD/ADHD. Of the 40 athletes with one concussion, 60.0% (n=24) reported no neurological diagnosis, 15.0% (n=6) reported LD, 17.5% (n=7) reported ADD/ADHD, and 7.5% (n=3) reported both LD and ADD/ADHD. Of the 31 athletes with 2 or more concussions, 74.2% (n=23) reported no neurological diagnosis, 9.7% (3) reported LD, 12.9% (n=4) reported ADD/ADHD, and 3.2% (n=1) reported both LD and ADD/ADHD.

A concussion severity index was created by assigning points to each grade of concussion (i.e. Grade 1 = 1 point, Grade 2 = 2 points, and Grade 3 = 3 points), then summing the total points each participant accumulated with successive concussions. The severity levels range from 0 to 9 and are assigned according to various combinations of the number and grade of concussions a participant had reported. For example, a participant with two Grade 1 concussions and one Grade 3 concussion would have a concussion severity index of 5 which is the sum of (2x1)+(1x3). The mean concussion severity index for this sample was 2.19 with a standard deviation of 2.25. A listing of all possible combinations for each severity level with a maximum of four concussions can be found in Table 4 (Appendix G, page 80). The four concussion maximum reflects the maximum number of concussions reported by any one participant in this study. However, the scale can be used for frequencies greater than four. The frequencies, valid percent, and cumulative percent of the concussion severity index for this sample can be found in Table 5 (Appendix G, page 82).

Statistical analysis was conducted using the SPSS-X statistical analysis computer program. Analyses of the relationship between race, grade in school, the order of tests, and the three primary dependent measures were conducted using separate one-way ANOVAs. The results indicate that neither race, grade, nor the order in which the tests were administered had an effect on the CPT, SAC, or Digit Symbol.

The means and standard deviations between groups on the dependent measures are included in Table 6 (Appendix G, page 83). A multiple analysis of variance (MANOVA) measuring the effects of the two levels of the concussion variable and two levels of the neurological condition variable on the three primary dependent measures (SAC total score, CPT - Reaction Time, and Digit Symbol) indicated mixed results with no significant effect on the Digit Symbol score for any group. For the neurological condition variable, there were significant main effects demonstrated on the CPT-Reaction Time ($F(1,102) = 9.03$, $\underline{p} \leq .01$) and on the SAC total score ($F(1, 102) = 8.66$, $\underline{p} \leq .01$). For the concussion variable, there was a significant main effect on the CPT-RT ($F(1,102) = 5.08$, $\underline{p} \leq .05$). There was a significant interaction between concussion history and neurological dysfunction on the CPT-Reaction Time score ($F(1,102) = 6.25$, $\underline{p} \leq .05$). See Table 7 (Appendix G, page 84) for a summary of the results including mean square errors.

When CPT-commission and CPT-index scores are included in the multivariate analysis, there is a significant main effect for the concussion variable on the CPT-commission score ($F(1,102) = 6.69$, $\underline{p} \leq .05$) and a significant main effect for the neurological condition variable on the CPT-index ($F(1,102) = 5.64$, $p \leq .05$) .

To control for shared variance among the dependent variables, univariate and stepwise analyses were completed. For this unbablaced data, sums of squares were calculated using the regression method, in which each identified effect is adjusted for all other effects in the model. The results of the univariate tests of the effects of concussion on the three main dependent measures, SAC, Digit Symbol, and CPT-reaction time and the two additional measures, CPT index and CPT commission errors, are presented in Table 8 (Appendix G, page 85). Using the Roy-Bargman Stepdown F-test, it is evident that the CPT-Reaction Time accounts for significant variance ($F(1,99) = 4.38$, $p \leq .05$), but that the other measures do no add significant unique variance to the equation. The results of the univariate tests of the effects of neurological condition on the three main dependent measures, SAC, Digit Symbol, and CPT-reaction time and two additional measures, CPT index and CPT commission errors, are presented in Table 9 (Appendix G, page 86). This time, the Roy-Bargman Stepdown F-test indicated that both the CPT-Reaction Time ($F(1,99) = 8.86$, $p \leq .01$) and the SAC ($F(1,98) = 9.99$, $p \leq .01$)contribute significant variance to the analysis, but that there is no significant unique variance contributed by the other measures.

A MANOVA was conducted to explore the effects of the concussion variable and neurological condition variable on the four subtests of the SAC. There was a significant main effect for neurological condition on the concentration subtest ($F(1,97) = 4.40$, $p \leq .05$) indicating that those participants with LD, ADD or ADHD, or both generally scored lower on the tasks that required recitation of the months of the year backwards, and repeating digits backwards than did their cohorts who did not report any of these predisposing conditions.

The next analyses were conducted to assess the relationships among a variety of measures including breakdowns of the SAC and the CPT-II for the total sample. Pearson product-moment correlations were calculated between the SAC total score, subtests of the SAC, the CPT-II-index score, reaction time score, and commission error score, digit symbol, and the concussion severity index and are reported in Table 10 (Appendix G, page 87). The correlation between subtests of the same instrument and of subtests or scales with the total or index scores of the same instrument are correlated, as would be expected due to shared variance. There was a positive correlation between total years of contact sports and the total number of concussions sustained (r = .378; $p < .01$) and between total years of contact sports and the concussion severity index (r = .277; $p < .05$) as was expected. There was a negative correlation between the number of concussions and SAC-delayed memory (r = -.248; $p < .05$) indicating that a greater number of reported concussions is associated with lower scores on this five item measure of delayed memory which requires the participant to recall a previously rehearsed list of words. There was a positive correlation between child reported NBSC scores and the concussion severity index (r = .367; $p < .01$) indicating that a greater number and severity of reported concussions is associated with a greater number of neurological and/or behavioral symptoms reported by the participant. A negative correlation was found between student reported grades and parent reported behaviors on three of the four scales of the CPRS-R:S; Cognitive

Problems/Inattention ($r = -.643$; $p < .01$), Hyperactivity ($r = -.282$; $p < .05$), and the ADHD Index ($r = -.469$; $p < .01$) indicating that a higher number of items endorsed by the parent or guardian as reflective of the participants behavior is associated with lower grades.

Discussion

The short- and long term effects of concussion have been demonstrated in a variety of studies (Barth, 1998; Collins, et al., 1999; Hinton-Bayre, et al., 1999; Macciocchi et al., 1996) but there remains no consensus about the conclusions drawn. Concussion research has recently focused on contact sports because of the high incidence of concussion in this population. In a study by Gerberich et al. (1983), 19% of the 3,063 football players surveyed reported a concussion characterized by loss of consciousness or loss of awareness in a single season. In this sample of 106 male, adolescent athletes, 71 (67%) reported at least one concussion during the course of their lifetime. There is currently no way to accurately predict which athletes will recover quickly and completely, and which ones will experience post concussive symptoms for an extended period of time.

For an injury that occurs with such regularity, it is important to identify the risk factors associated with the incidence and recovery of athletes with concussion. This is especially important in contact sports and in children and adolescents because of poorly understood, but potentially serious complications of acute concussion that result in life-threatening events such as Second Impact Syndrome (McCrory & Berkovic, 1998) and of chronic conditions such as Dementia Pugilistica (Erlanger et al., 1999).

Neuropsychological assessment is proving to be not only a cost-effective and time efficient way to assess a concussive injury, but in some cases, may also be able to detect the more subtle deficits that may not be evident on neurological examination or neuroimaging studies. However, even the traditional neuropsychological testing battery may not accurately detect post-concussive changes because it is designed to identify specific or discreet function loss, not the more global or diffuse injury often seen in concussion. This is especially true of the type of injury most often incurred in some contact sports which is caused by rotational or acceleration-deceleration forces and characterized by function loss which is less specific, affects more than one area of the brain, and affects higher order skills or those requiring divided attention. Efforts are underway to identify assessment instruments sensitive to the changes which often follow a concussive injury.

The goal of much of the recent research is to identify a brief, but inclusive assessment battery to accurately diagnose concussion and rate its severity. Consistent use of a standardized battery will assist coaches, trainers, and others in making diagnostic and return-to-play decisions. But as with any type of assessment, special populations do not always perform as does the standardization sample, and inferences based on test scores are not always accurate. The importance of the identification of conditions that systematically effect performance on assessment is evident. Research indicates that there are premorbid risk factors that significantly impact the pre-injury performance and post-injury recovery on some neuropsychological assessments. Research also indicates that the presence of certain risk factors premorbidly may actually increase one's risk of sustaining a concussion, and when a concussion does occur, the effects of the injury may be more pronounced and the recovery rate may be atypical (Collins, Grindel, et al., 1999; Teasdale & Engberg, 1997; Gerberich et al., 1983).

Among the premorbid conditions that may effect injury acquisition, severity, and recovery are neurological syndromes such as learning disabilities and attention deficit disorder (with or without hyperactivity). There is also a growing body of evidence that there is a genetic predisposition for injury in the APOE epsilon 4 allele, and evidence that previous head injury or concussion may be an important risk factor for concussion acquisition and severity.

This research demonstrated the differential effects of neurological conditions such as LD, ADD, and ADHD in an athlete's performance on two measures; the reaction time component of the CPT-II and the total score for the SAC. The CPT-Reaction Time test was also shown to discriminate between the concussed and nonconcussed groups. Reaction time tests are among an emerging group of tests that may be sensitive to the subtle, but sometimes long-term effects of concussion.

The SAC is a standardized assessment of concussion with growing popularity due to the ease of administration (on the sideline by trained, but non-medical professionals) and proven efficacy in identifying immediate and short term effects of concussion. In this study, the SAC subtest Concentration was differentially effected by the presence of a premorbid neurological condition as well. While the concentration subtest of the SAC consists of only five items, concentration tasks may prove to be an area of research to revisit.

Implications for Practice.

Pretesting of junior high and high school athletes at the beginning of each school year or before the sports season may provide information which will make the diagnosis and management of acquired concussion most efficacious. This is especially true for athletes with premorbid neurological conditions such as LD, ADD, and ADHD, as their scores on pretesting can differ significantly from those athletes without these conditions.

This collective research may improve the diagnosis, treatment, and identification of long term deficits of concussion and associated risk factors. It may also identify special populations whose performance must be evaluated in light of differences in pre- and post injury performance. With continuing research in this area, empirical evidence may assist clinical decisions regarding concussion assessment and treatment.

Implications for Future Research.

This study provided a snapshot of the cognitive functioning of 106 athletes on tasks that are designed to measure sustained attention, reaction time, information processing, and post-concussive symptoms. It identified differences in pre-test performance between those with neurological conditions such as ADD, ADHD, and LD and those without. But much remains unclear. Contrary to what was predicted, there was no systematic effect of concussion on the dependent variables. This effect was absent not only when comparing the number of concussions sustained, but when the number and severity of concussions were combined to create a concussion severity index. Other factors that were not investigated, but would probably influence the effects of concussion on the instruments used include the age of the child at the time of the incident or incidents, and the amount of time between the incident and the testing. Gender differences may also prove to be an interesting variable as may the type of sport and associated risks due to normal play and to particular positions on the team or style of playing.

The SAC is a promising tool for standardized diagnosis of concussion on the sideline. It has a relatively low ceiling effect with the majority of athletes scoring in the normal range, but may be especially useful for gross assessment and as a baseline for a recovery curve. The more sensitive instruments such as reaction time, commission errors, information processing, and others will continue to be investigated as possible indicators of the long term or cumulative effects of concussion.

Data collection on athletes with and without a history of concussion was characterized by generally enthusiastic willingness to participate in a study that focused on a topic with which most of them were familiar. However, the predicted portion of those athletes with a history of ADD, ADHD, and LD was under-represented either because fewer students with these conditions play sports or because they systematically avoided participation. One possible explanation is that students with these conditions may have developed a bias against testing because of past negative experiences in their academic history. It is understood that they might choose to avoid a situation that was generally aversive to them and that might demonstrate their weaknesses.

The efficacy of the use of the SAC, the CPT-II, and the Digit Symbol as measures of concussion effects would be more fully demonstrated in a study that pretested a larger number of athletes and then followed them over the course of a season or more so as to track performance on tasks in relation to the number and severity of concussions sustained and the length of recovery. This would allow matched controls to serve as comparisons and could net more meaningful results.

Understanding the differences on test performance between athletes with and without neurological conditions may be conducive to more accurate diagnosis and treatment of concussion effects.

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APPENDICES

APPENDIX A

Glasgow Coma Scale

Eye Opening		
Spontaneous	4	
To voice	3	
To pain	2	
None	1	
Best Verbal Response		
Oriented	5	
Confused	4	
Inappropriate words	3	
Incomprehensible	2	
None	1	
Best Motor Response		
Obeys Commands	6	
Localizes Pain	5	
Withdraws from pain	4	
Flexes to pain	3	
Extends to pain	2	
None	1	
Possible Total Range		3 -15

APPENDIX B

Concussion Assessment

In order to assess the number and type of concussions you have experienced, please indicate the nature of each of your injuries below.

Concussion Number _____
When did it happen? Month_____ Year_______
Did you lose consciousness? Yes____ No____
If yes, how long were you unconscious? 10 seconds or less_____
10 seconds to one minute______
One to five minutes_______
More than five minutes____ # of minutes unconscious ___
How did it happen? (car accident, sports injury, fall, etc.)____________________________
____

Place an "X" in the column to the left of the symptoms that lasted **15 MINUTES OR LESS** after the accident and place an "X" in the column to the right of the symptoms that lasted **LONGER THAN 15 MINUTES** after the accident.

After the Injury, lasted 15 MINUTES OR LESS	SYMPTOM	After the injury, lasted LONGER THAN 15 MINUTES
	Confusion	
	Memory problems	
	Shakiness or unsteadiness	
	Dizziness	
	Weakness or tiredness	
	Decreased coordination	
	Brief blackout or greyout	
	Double or blurred vision	
	Sensitive to light or sound	
	Ears ringing	
	Headache	
	Decreased concentration	
	Decreased attention	
	Nausea	
	Appetite change	
	Sleep change	
	Worry	
	Depression	
	Withdrawal	
	Irritabiltiy	
	Other	
	Other	

APPENDIX C

Demographic Information

(To be completed by the participating athlete)

Name: ____________________ Date of Birth ____________________
Age: ________ Grade in School ____________________
Address:____________________ Phone number where you can be reached
____________________ ____________________

Ethnic Background: *circle one* **African American** **Asian** **Caucasion (white)** **Hispanic** **Native American** **Other (please specify______________)**
Mother's name ____________________Mother's phone #s__________ __________
Father's name ____________________Father's phone #s __________ __________
With whom do you live?____________________
Please list the sport(s) you play or have played and the number of years playing that sport.
Sport__________# of years__________ Sport__________# of years__________
Sport__________# of years__________ Sport__________# of years__________
Sport__________# of years__________ Sport__________# of years__________

Indicate those areas which have sustained a sports related injury severe enough to need treatment?
Circle all that apply **ankle** **knee** **hip** **arm** **leg** **elbow** **shoulder** **neck** **back** **ribs** **pelvis** **wrist** **nose**
Do you maintain a part time job during the school year? **YES** **NO** If yes, for how many hours each week?____
Which exam have you taken most recently? *circle one* **SAT/ACT/PSAT**? Your score was _______.
What are your average grades this year?
__**mostly Fs** __**D-F** __**mostly Ds** __**C-B** __**mostly Cs** __**B-C** __**mostly Bs** __**A-B** __**mostly As**
What is your weakest subject(s)?____________________
What is your strongest subject(s)?____________________
Have you ever been tested because you had difficulty in school? circle *one* **YES** **NO**
Have you ever been diagnosed with....

ADHD? *circle one* **YES** **NO** if yes, when? ____
Learning Disability? *circle one* **YES** **NO** if yes, when? ____
Reading Disability? *circle one* **YES** **NO** if yes, when? ____
Developmental Disability? *circle one* **YES** **NO** if yes, when? ____
Behavior Problem? *circle one* **YES** **NO** if yes, when? ____

Have you ever had a tutor? *circle one* **YES** **NO** if yes, when? _____ If yes, in what subject(s)? ____________________
Have you ever missed a sporting event because of your grades? *circle one* **YES** **NO** # of times__________
Have you ever been expelled from a school for a behavior problem? *circle one* **YES** **NO** # of times__________
Have you ever had in-school or out-of-school suspension? *circle one* **YES** **NO** # of times__________
What medications do you currently take? (include prescription medications, over the counter medications and health supplements)____________________
The average number of cigarettes you smoke per week is? __**0** __**1-2** __**3-5** __**6-10** __**11-20** __**21-30** __**30+**
The average number of alcoholic beverages you drink per week is? __**0** __**1-2** __**3-5** __**6-10** __**11-20** __**21-30**
The average number of marijuana cigarettes you smoke per week is? __**0** __**1-2** __**3-5** __**6-10** __**11-20** __**21-30**
Have you ever had unprotected sex? *circle one* **YES** **NO**
Have you ever been stopped for speeding? *circle one* **YES** **NO**

APPENDIX D

Medical and Academic Information

(To be completed by the participating athlete's parent or guardian)

Please answer all questions (all information will be kept confidential).

1. Name of child: ______________________ Date of Birth: ____________________
2. Mother's name ______________________ Mother's phone #s ________________
3. Mother's address ______________________ ________________
4. Father's name ______________________ Father's phone#s ________________
5. Father's address ______________________ ________________
6. Name of person completing this form ______________________ Phone# ________________
7. Name of person who provided signed consent ______________________ Phone# ________________
8. With whom does the child live? Mother_____ Father_______ Both_______ Other ________
9. If other, please provide their name, address, phone and how they are related to him (e.g. guardian, grandparent, foster parent, sibling).
10. Name ______________________ Relationship ________________
11. Address ______________________ Phone#s ________________

Circle Yes, No, or DK(don't know)

12. What was the mother's age at the time of this child's birth? ____________
13. Were there any complications during the pregnancy or delivery of this child? **YES NO DK**
14. Was this child born prematurely (before 38 weeks) **YES NO DK**
15. Did this child suffer from any serious childhood illness or accident? **YES NO DK**
16. If yes, please provide ages and circumstances ______________________
17. Please list any other surgeries or hospitalizations ______________________
____
18. Does this child seem unusually accident prone? **YES NO DK**
19. Has this child ever repeated a grade? **YES NO DK**
If yes, which one(s) __________
20. Has this child ever been in a special class for all or part of the school day? **YES NO DK**
21. Has this child been diagnosed with.... Do you think this child has.....

22. ADHD.......... **YES NO**	23. ADHD.......... **YES NO**
24. Learning Disabilities.......... **YES NO**	25. Learning Disabilities.......... **YES NO**
26. Reading Disability.......... **YES NO**	27. Reading Disability.......... **YES NO**
28. Developmental Disability.. **YES NO**	29. Developmental Disability.. **YES NO**
30. Behavior Problem.......... **YES NO**	31. Behavior Problem.......... **YES NO**

32. Has this child ever sustained a traumatic brain injury? **YES NO**
If yes, please provide dates and circumstances ______________________
33. Approximately how many concussions has this child sustained (confusion, amnesia, memory loss, or brief loss of consciousness following a blow to the head)? ______________
34. What medications does this child currently take? (include prescription medications, over the counter medications and health supplements) ______________________
____
35. Does this child smoke at least one cigarette per week? **YES NO DK**
36. Does this child consume at least one alcoholic beverage per week? **YES NO DK**
37. Does this child smoke marijuana? **YES NO DK**
38. Is this child sexually active? **YES NO DK**
39. Does this child have a driver's license? **YES NO DK**
If so, has he been stopped for speeding or reckless driving? **YES NO DK**

40. May I call you if I have any additional questions? **YES NO**
Please provide the number and time of day you would prefer to be called.
number ______________ time of day ________________

APPENDIX E (1)

Consent Form - *Parent/Guardian*

for research conducted under the auspices of the
University of Oklahoma - Norman Campus

This research project titled "Concussion Risk in High School Football" is being conducted by Janelle Grellner, M.A. in partial fulfillment of requirements for a Ph.D. in Counseling Psychology from the University of Oklahoma.

Your signature on this document indicates your consent to participate in this research project. In order for an athlete to participate, the athlete and the athlete's parent/guardian must each provide signed consent at the bottom of the forms as indicated. Your signature also indicates consent for information to be obtained from athletic records and/or academic records for your child. This will enable use of information already available and may shorten the amount of information you need to provide.

Description of the study. The athletes who participate will undergo an approximately 30 minute assessment which includes a paper and pencil test of concentration, a computer-based test of reaction time, a test designed to assess an athlete in the event of a concussion, a symptom checklist, and some information forms. Some athletes some be re-assessed using the same tests after a two month period A parent/ guardian of each athlete will complete a brief child behavior checklist, an academic-medical history form, and a symptom checklist at the beginning of the season (total time 10 minutes or less)

Risks and benefits. There are no foreseeable risks associated with participation in this study. Aside from the testing sessions, no other disruption to the athlete's routine is foreseen.

Benefits of participation include active contribution to research designed to better understand and treat concussion in sports. The athletes and team staff will be provided with the most recent concussion assessment procedures. Knowledge obtained from this study and others like it may lead to improved management of concussion and reduction of serious injury resulting from concussion. The research findings will be made available to the team staff and players and may be published in a professional journal.

Rights Regarding Participation and Confidentiality. The University of Oklahoma supports the practice of protection of human participants in research. All experiments are approved by an internal review board and meet Federal Guidelines Protecting Human Subjects. The athlete's participation is encouraged, but is strictly voluntary. The athlete is free to refuse to participate in any procedure or to refuse to answer any question at any time without penalty. The athlete has the right to withdraw at any time without penalty. You can be assured that the athlete's name will not be associated in any way with the research findings. Information about the athlete will be kept confidential. Once data is collected, individual protocols will be coded with the names removed and kept in a locked filing cabinet.

Questions or Comments. You may contact Janelle Grellner at (405) 263-4558 if you have questions related to this study. Furthermore, research participants and their parents/guardians may contact the Office of Research Administration at (405) 325-4757 for additional information on participant's rights.

Signed Consent. *I hereby consent to allow participation of ____________________ (athlete's name) in the above-described research. I understand that participation is voluntary and that this athlete may withdraw at any time without penalty or loss of benefits.*

Printed Name of Parent/Guardian: ____________________ ***Relationship to athlete:*** ________________

Signature of Parent/Guardian: ______________________________ ***Date:*** ________________

APPENDIX E (2)

Assent Form - *Athlete*

for research conducted under the auspices of the University of Oklahoma - Norman Campus

This research project titled "Concussion Risk in High School Football" is being conducted by Janelle Grellner, M.A. in partial fulfillment of requirements for a Ph.D. in Counseling Psychology from the University of Oklahoma.

Your signature on this document indicates your consent to participate in this research project. In order for an athlete to participate, the athlete and the athlete's parent/guardian must each provide signed consent at the bottom of the forms as indicated. Your signature also indicates consent for information to be obtained from athletic records and/or academic records for your child. This will enable use of information already available and may shorten the amount of information you need to provide.

Description of the study. The athletes who participate will undergo an approximately 30 minute assessment which includes a paper and pencil test of concentration, a computer-based test of reaction time, a test designed to assess an athlete in the event of a concussion, a symptom checklist, and some information forms.

A parent/ guardian of each athlete will complete a brief child behavior checklist, an academic-medical history form, and a symptom checklist at the beginning of the season (total time 10 minutes or less).

Risks and benefits. There are no foreseeable risks associated with participation in this study. Aside from the testing sessions, no other disruption to the athlete's routine is foreseen. Treatment considerations will be made per the team and parental guidelines with no recommendations made related to test results.

Benefits of participation include active contribution to research designed to better understand and treat concussion in sports. The athletes and team staff will be provided with the most recent concussion assessment procedures. Knowledge obtained from this study and others like it may lead to improved management of concussion and reduction of serious injury resulting from concussion. The research findings will be made available to the team staff and players and may be published in a professional journal.

Your Rights Regarding Participation and Confidentiality. The University of Oklahoma supports the practice of protection of human participants in research. All experiments are approved by an internal review board and meet Federal Guidelines Protecting Human Subjects. Your participation is encouraged, but is strictly voluntary. You are free to refuse to participate in any procedure or to refuse to answer any question at any time without penalty. You have the right to withdraw at any time without penalty. You can be assured that your name will not be associated in any way with the research findings. Information about you will be kept confidential. Once data is collected, individual protocols will be coded with the names removed and kept in a locked filing cabinet.

Questions or Comments. You may contact Janelle Grellner at (405) 263-4558 if you have questions related to this study. Furthermore, research participants and their parents/guardians may contact the Office of Research Administration at (405) 325-4757 for additional information on participant's rights.

Signed Consent. I hereby agree to participate in the above-described research. I understand my participation is voluntary and that I may withdraw at any time without penalty or loss of benefits.

Printed Name of Student: ______________________________

Signature of Student: ________________________________ ***Date:*** ____________________

APPENDIX F

The University of Oklahoma

OFFICE OF RESEARCH ADMINISTRATION

April 11, 2001

Ms. Janelle Grellner
PO Box 94
Okarche OK 73762

Dear Ms. Grellner:

The Institutional Review Board-Norman Campus has reviewed your proposal, "Concussion Risk in High School Football," under the University's expedited review procedures. The Board found that this research would not constitute a risk to participants beyond those of normal, everyday life, except in the area of privacy, which is adequately protected by the confidentiality procedures. Therefore, the Board has approved the use of human subjects in this research.

This approval is for a period of twelve months from this date, provided that the research procedures are not changed significantly from those described in your "Application for Approval of the Use of Humans Subjects" and attachments. Should you wish to deviate significantly from the described subject procedures, you must notify me and obtain prior approval from the Board for the changes.

At the end of the research, you must submit a short report describing your use of human subjects in the research and the results obtained. Should the research extend beyond 12 months, a progress report must be submitted with the request for re-approval, and a final report must be submitted at the end of the research.

Sincerely yours,

Susan Wyatt Sedwick

Susan Wyatt Sedwick, Ph.D.
Administrative Officer
Institutional Review Board-Norman Campus

SWS:pw
FY01-9

Cc: Dr. E. Laurette Taylor, Chair, Institutional Review Board
Dr. Terry Pace, Counseling Psychology

APPENDIX G

TABLES

APPENDIX G

Table 1

Comparison of Cantu, Colorado, and AAN Guidelines for Concussion Classification

Severity	Cantu	Colorado	AAN
Grade 1	classified as mild		
	no LOC	no LOC	no LOC
	PTA < 5 minutes	confusion/no amnesia	transient
		concussive symptoms	confusion
		or MS abnormalities	
		< 15 min.	
Grade 2	classified as moderate	classified as moderate	
	LOC < 5 minutes	no LOC	no LOC
	-or-		
	PTA > 30 minutes	confusion with	transient
		amnesia	confusion
Grade 3	classified as severe	classified as severe	
	LOC > 5 minutes	LOC	any LOC (brief or
	-or-		prolonged)
	PTA > 24 hours		

Note. LOC = Loss of Consciousness; PTA = Post Traumatic Amnesia; MS = Mental Status

APPENDIX G

Table 2

Comparison of Colorado, Lablanc, and AAN Return to Play Guidelines

Severity	Colorado Guidelines	Lablanc	AAN
Grade 1	Remove from contest, examine immediately and every 5 min. for amnesia or PCS. May return if asymptomatic and no amnesia for 20 min.	Return to play 1 week after completely asymptomatic	None available
Multiple Grade 1	None available	2nd Grade 1: Return 2weeks after asymptomatic; normal CT scan. 3rd Grade 1: No return for the rest of season.	Return in 1 week

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Grade 2	Remove from contest Examine frequently for evolving intracranial pathology, re-examine next day. Return 1 week after asymptomatic.	Return 2 weeks after asymptomatic	Return in 1 week
Multiple Grade 2	None available	2nd Grade 2: return 1 month after asympto-matic and normal CT. 3rd Grade 2: No return for rest of season.	Return in 2 weeks
Grade 3	Transfer to hospital by ambulance for neurological eval. Return 2 weeks after asymptomatic	Return 1 month after after asymptomatic and normal CT.	Brief LOC (seconds): return in 1 week Lengthy LOC: return in 2 wks.
Multiple Grade 3	None available	2nd Grade 3: No return for rest of season.	1 month or longer

Note. LOC = Loss of Consciousness; CT Computed Tomography

APPENDIX G

Table 3

Number of Participants in Each Group of a 2 x 2 design.

	Neurological Condition	
	None	ADD/ADHD/BOTH
Concussion History		
None	N = 25	N = 10
One or more	N = 47	N = 24

APPENDIX G

Table 4

Concussion Number and Severity Combinations Comprising the Concussion Severity Index

Severity index	Possible combinations
0	none
1	one grade 1
2	two grade 1
	one grade 2
3	three grade 1
	one grade 1 and one grade 2
4	one grade 1 and one grade 3
	two grade 1 and one grade 2
	two grade 2
5	one grade 1 and two grade 2
	two grade 1 and one grade 3
	three grade 1 and one grade 2
	one grade 2 and one grade 3

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6	one grade 1 and one grade 2 and one grade 3
	two grade 1 and two grade 2
	three grade one and one grade 3
	three grade 2
	two grade 3
7	one grade 1 and two grade 3
	one grade 1 and three grade 2
	two grade 1 and one grade 2 and one grade 3
	two grade 2 and one grade 3
	three grade 1 and two grade 2
8	one grade 1 and two grade 2 and one grade 3
	two grade 1 and two grade 3
	one grade 2 and two grade 3
	four grade 2
9	one grade 1 and one grade 2 and two grade 3
	two grade 2 and one grade 3
	three grade 2 and one grade 3
	three grade 3

Note. The table includes combinations which include between one and four concussions because four was the maximum number reported by this sample.

APPENDIX G

Table 5

Frequency, Valid Percent, and Cumulative Percent of Concussion Severity Index for Sample of 106 Male Athletes Ages 14-19

Severity Index Score	Frequency	Valid Percent	Cumulative Percent
0	35	33.3	33.3
1	13	12.4	45.7
2	21	20.0	65.7
3	8	7.6	73.3
4	9	8.6	81.9
5	7	6.7	88.6
6	6	5.7	94.3
7	5	4.8	99.0
9	1	1.0	100.0
Missing	1		
Total	106		

APPENDIX G

Table 6

Means and Standard Deviations on Three Primary Dependent Variables

	CPT-RT X (S.D.)	SAC X (S.D.)	DS X (S.D.)
No Concussion			
No Neuro	327.58 (43.38)	26.72 (1.78)	75.48 (14.69)
Neuro	383.66 (75.80)	25.60 (1.50)	69.60 (12.65)
One + Concussion			
No Neuro	330.08 (41.87)	27.04 (1.73)	74.13 (13.25)
Neuro	335.27 (36.79)	25.75 (2.13)	69.17 (13.43)

Note. CPT-RT = Continuous Performance Test-Reaction Time; SAC = Standardized Assessment of Concussion Total Score; DS = Digit Symbol; Neuro = Neurological Condition.

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Table 7

Multiple Analysis of Variance for Effects of Concussion and Neurological Condition on Three Primary Dependent Variables

		F		
Source	df	CPT-RT	SAC	DS
Concussion (C)	1	5.076*	.332	.085
Neurological Condition (NC)	1	9.033**	8.659**	3.136
C x NC	1	6.247*	.044	.023
S within-group error	102	(2045.558)	(3.312)	(184.679)

Note. Values enclosed in parentheses represent mean square errors. CPT-RT = Continuous Performance Test-Reaction Time; SAC = Standardized Assessment of Concussion Total Score; DS = Digit Symbol; S = subjects.

*$p < .05$. **$p < .01$.

APPENDIX G

Table 8

Univariate and Stepdown F-Tests for Concussion Variable Main Effect

Analysis	Dependent Variable		F	Sig
Univariate F-test	CPT-Reaction Time		4.38	0.04
(1,99) D.F.	SAC		0.26	0.61
	CPT-Index		0.44	0.50
....	Digit Symbol		0.07	0.79
....	CPT-Commision Errors		5.48	0.02
Roy-Bargman		Error D.F.		
Stepdown F-test	CPT-Reaction Time	99	4.38	0.03
....	SAC	98	0.57	0.45
....	CPT-Index	97	0.01	0.91
	Digit Symbol	96	0.77	0.38
	CPT-Commission	95	1.54	0.21

APPENDIX G

Table 9

Univariate and Stepdown F-tests for Neurological Condition Variable Main Effect

Analysis	Dependent Variable		F	Sig
Univariate F-test	CPT-Reaction Time		8.86	0.00
(1,99) D.F.	SAC		8.50	0.00
	CPT-Index		5.64	0.02
	Digit Symbol		3.42	0.07
....	CPT-Commision Errors		0.09	0.76
Roy-Bargman		Error D.F.		
Stepdown F-test	CPT-Reaction Time	99	8.86	0.00
....	SAC	98	9.99	0.00
....	CPT-Index	97	1.58	0.21
	Digit Symbol	96	0.00	0.96
	CPT-Commission	95	2.61	0.10

APPENDIX G

Table 10

Intercorrelations Between Dependent Measures.

	C-RT	C-C	Ind	DS	SAC	Ort	Mem	Con	D-Rec
C-RT	1	-.52**	.04	.39**	-.18*	.04	-.06	-.01	.12
C-C		1	.07	-.21*	-.11	.02	.01	-.04	.04
Ind			1	-.26**	-.01	-.02	-.02	.04	-.03
DS				1	.34**	.11	.01	.24**	.31**
SAC					1	.42**	.17*	.68**	.59**
Ort						1	.03	.08	.19*
Mem							1	.04	-.12
Con								1	.16*
D-Rec									1

Note. C-RT = CPT Reaction Time; C-C = CPT Commission Errors; Ind = CPT Index Score; DS = Digit Symbol; SAC = Standardized Assessment of Concussion Total Score; Ort = SAC Orientation; Mem = SAC Immediate Memory; Con = SAC Concentration; D-Red = SAC Delayed Recall. *$p < .05$ **$p < .01$.