TRAUMATIC BRAIN INJURY IN SPORTS
TRAUMATIC BRAIN INJURY IN SPORTS

AN INTERNATIONAL NEUROPSYCHOLOGICAL PERSPECTIVE

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Contents

FROM THE SERIES EDITOR ix

INTRODUCTION xi

SECTION I BASIC CONCEPTS
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CHAPTER 1 HISTORICAL PERSPECTIVES 3
Scott D. Bender, Jeffrey T. Barth, and James Irby

CHAPTER 2 DIAGNOSIS, MANAGEMENT, AND PREVENTION 23
John W. Powell

CHAPTER 3 BIOMECHANICS OF BRAIN INJURY IN ATHLETES 35
James A. Newman

CHAPTER 4 THE PATHOPHYSIOLOGY OF TRAUMATIC BRAIN INJURY 45
Christopher C. Giza and David A. Hovda

CHAPTER 5 NEUROIMAGING IN SPORTS-RELATED BRAIN INJURY 71
Erin D. Bigler and William W. Orrison

CHAPTER 6 GENETIC ASPECTS OF TRAUMATIC BRAIN INJURY IN SPORTS 95
Barry D. Jordan
From the Series Editor

I am most happy to introduce *Traumatic Brain Injury in Sports: A Neuropsychological and International Perspective* as the next volume in our series. This text, edited by and including contributions from many of the most prominent researchers in the field, provides a comprehensive review of neuropsychological studies in an international range of sports, ranging from South African rugby to equestrian sports, as well as professional American football, hockey, and boxing. In addition, the text addresses the necessary methodological issues and practical considerations which need to be considered in studies and evaluations in this field, as well as neuroimaging findings, biomechanics, and pathophysiology, and even the potential for relationships of sports injury to the genetic context. One will find here a ready reference to the range of neuropsychological issues that needs to be addressed in the context of clinical evaluations as well as study design. Ethical and age-related caveats are treated as well. I trust that the reader will be satisfied with this addition to our continuing focus on the interface between empirical research and its useful clinical consideration.

*Linas A. Bieliauskas*

Ann Arbor, July 2003
Introduction

Like all fledgling disciplines, Sports Neuropsychology is undergoing very rapid development. This book represents a compilation of contemporary thought and published research in the field. In addition to serving as a comprehensive review of neuropsychological approaches to the management of mild traumatic brain injury (concussion), this book has also been designed to provide an international perspective on the subject of concussion in sports. This perspective was adopted to highlight both similarities and differences between assessment and treatment strategies throughout the world and to advance the overall state of knowledge internationally.

*Traumatic Brain Injury in Sports: an International Neuropsychological Perspective* has been structured to cover four core areas of interest. *Section I* begins with a historical view of application of neuropsychological assessment in sports. A chapter that provides an epidemiological perspective follows this chapter. Next, the focus of the book moves to a discussion of the biomechanical, neurometabolic and neuroanatomical aspects of concussion (Chapters 3, 4 and 5). These chapters are designed to provide the reader with a state-of-the-art understanding of the forces that lead to concussion as well as the acute and more chronic changes in brain function and structure that can occur, even following seemingly mild injury. The section concludes with a review of the potential genetic contributions to injury vulnerability and recovery. In addition to reviewing the specific topics listed above, *Section I* attempts to meld current research gleaned form both animals and human subjects into a more coherent understanding of the neurophysiological recovery process following concussion. The question of when brain metabolism returns to normal is not just an issue of academic interest but, as illustrated throughout this book, may have a direct impact on long-term brain function and individual psychological, social, and academic adjustment.

*Section II* is structured to provide a review of current Neuropsychological assessment programs throughout the world that have been designed to help sports-medicine personnel make more informed decisions regarding the return to play within specific sports environments. This section provides a
panoramic view of the spectrum of sports-related concussion throughout both amateur and professional sports. Specifically, the sports of ice hockey, American football, soccer, boxing, Australian rules football, rugby and equestrian events are discussed in some detail, highlighting both differences and similarities between sports and discussing sports specific clinical approaches to concussion management. Differences between amateur and professional sports are specifically discussed as these environments differ substantially regarding the design of neuropsychological assessment programs, their implementation and how return to play decisions are made following injury.

In contrast to the largely clinical perspective presented in Section II, Section III provides a comprehensive review of technical and methodological issues germane to the use of neuropsychological assessment strategies in sports. Following an initial discussion of basic approaches to neuropsychological research within the context of sports, the important issues of reliability and validity in sports neuropsychology are discussed in detail. In addition to a basic discussion of reliability and validity issues, this section also provides a discussion regarding the implementation of new statistical techniques for the assessment of meaningful clinical change following injury. Finally, this section provides a thorough discussion of computer-based neuropsychological assessment procedures and their potential use in sporting environments. Computer-based neuropsychological assessment techniques represent an important advance that has led to the widespread implementation of neuropsychological testing procedures internationally.

The fourth and final section of this book is structured to review a variety of important topics that are highly relevant to the management of sports-related concussions. For instance, strategies for consultation with sports organizations are discussed in Chapter 21, with specific reference to work with high school, collegiate and professional sports organizations. Chapter 22 presents a discussion of current psychotherapeutic approaches to working with brain-injured athletes. Cultural issues in the neuropsychological assessment of athletes are discussed in Chapter 23 with an emphasis on the appreciation of how cultural factors can affect neuropsychological assessment results and the clinical interpretation of test results. Chapter 24 provides a comprehensive review of potential gender differences in response to brain injury and recovery. Chapter 25 reviews potential ethical conflicts and the resolution of these conflicts is discussed in this chapter. Finally, Chapter 26 provides a specific framework for making return-to-play decisions following concussion with consideration of neurological, neuropsychological, individual, and family issues.

References

SECTION I

BASIC CONCEPTS

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Chapter 1

HISTORICAL PERSPECTIVES

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The forced retirements of high-profile professional athletes such as Troy Aikman, Brett Lindros, and Steve Young have heightened the public’s awareness of concussion in sports. Researchers have now demonstrated that concussion is a common health problem with appreciable risk of sequelae, including persistent disability (Malec, 1999).

For years scientists and health care professionals have relied on neuropsychological tests for clinical evidence of very mild traumatic brain injury (mTBI). However, only relatively recently have these tests been used to assess mTBI and concussion in sports. In this time, neuropsychology has played a vital role in developing a definition of concussion, injury severity ratings, and return to play criteria. It also has improved outcome prediction based on neurocognitive functioning. Sports neuropsychology has emerged as an important area both for research in clinical neuropsychology (e.g., to describe neurocognitive effects of mild head injury in general) and for the protection of players (e.g., to document sports-related deficits and to predict recovery). This chapter provides an historical perspective, an introduction to the epidemiology and pathophysiology of mTBI, and a review of the current
status of assessment and classification in sports neuropsychology. Subsequent chapters provide more comprehensive discussions of these topics.

Historical Perspectives

Though the term “cerebral concussion” likely was not used with regularity until the Renaissance, references to what were probably concussions were made in ancient history. For example Hippocrates (460-370 BC) described in his writings a concussive-like syndrome involving head trauma, aphasia, and temporary unconsciousness. Galen (129-216 AD) appears to have made the first mention of sports-related brain injury in his writings on the gladiatorial games of the Roman Empire (McCrory & Berkovic, 2001).

In modern American history, very few safety regulations existed before President Theodore Roosevelt established the Intercollegiate Athletic Association of the United States (IAAUS) in 1906 (officially termed the National Collegiate Athletic Association [NCAA] in 1910). In 1904 alone, 19 players were killed or paralyzed playing football (Kelly, 1999), and the sport appeared to be growing in brutality. In response, leaders from Harvard, Yale and Princeton decided to change the rules to ban mass formations and gang tackling, and to include the forward pass. Approximately 70 years later, the rules of football again were changed to ban “spearing,” and the importance of protective gear received greater attention.

Prior to the 1980s mild brain injuries (whether sports-related or not) received relatively little attention, while moderate to severe brain injuries predominated the neurological and neuropsychological literature. Patients with mild brain injuries were thought to recover quickly and completely in the vast majority if not all cases. In fact, Miller (1961) proposed that those who were slow to recover from mTBI were experiencing “accident neurosis” (or “compensation neurosis”) and would recover once they had received remuneration for their injuries. Similar lines of thought pervaded the health community despite the work of Symonds (1962) and Oppenheimer (1968), who each cogently argued that the effects of mTBI were considerable and at times irreversible. Psychological weakness, psychiatric disturbance, or secondary gain (e.g., malingering) were considered to be more likely etiologies for poor recovery from mild brain injury.

Two lines of research shed more light on the observations of Symonds (1962) and Oppenheimer (1968) and opened the door to later rigorous study of mTBI. In animals, research by Gennarelli, Adams, and Graham (1981) revealed shear-strain injury to axonal fibers in the brainstems of mildly concussed primates. In humans, Gronwall and Wrightson (1974) reported slowed processing speed, impaired attention/concentration, and delayed return to work in mildly brain-injured patients. A few years later, Rimel, Giordani, Barth, Boll, and Jane (1981) found that 55% of all closed head injuries were classified as mTBI. Follow up study at 3 months post injury
showed that 34% had not returned to their previous level of employment. Numerous investigations have since documented neurocognitive deficits (Barth, Macciocchi, Boll, Giordani, & Rimel, 1983; Leininger, Gramling, Ferrel, Kreutzer, & Peck, 1990; Ruff et al., 1989) and occasionally parenchymal lesions (on MRI; e.g., Levin, Amparo et al., 1987) in mild brain-injured patients.

Despite the indications that mTBI might be more prevalent and serious than previously thought, disagreement continued regarding the definition, expected course, role of psychological factors, and pathophysiological mechanisms of mTBI (Barth, Diamond, & Errico, 1996). With respect to the definition of concussion, Wills and Leathem (2001) recently reviewed several studies of rugby injuries and found that only one investigator provided an operational definition of concussion. They suggest that there has been an over-reliance on loss of consciousness (LOC) as an indicator of concussion and that “true estimates [of concussion] are vastly underreported” (p. 647). The varied criteria for concussion and mTBI, inconsistent use of the terms “concussion” and “mTBI,” broad use of “minor” and “mild,” and confusion regarding the differences between “head” and “brain” injury appear to have created methodological confounds that limit the utility and generalizability of mTBI research.

Criticism regarding mild brain injury research methodology began at the outset. Early studies were criticized for (1) lacking generalizability to humans and (2) not adequately accounting for the effects of premorbid factors, such as prior head injury, substance abuse, pending litigation, or prior intellectual level. Research to address the latter criticism has reaffirmed findings of neurocognitive deficits in samples of mild brain-injured patients, especially those in the early stages of recovery (Dikmen, McLean, & Temkin, 1986; Levin, Mattis et al., 1987; McLean, Temkin, Dikmen, & Wyler, 1983). These studies were instrumental in changing the perception that mTBI was invariably an inconsequential ailment.

The Sports Arena as Clinical Neuropsychology Lab

The problems of finding adequate controls and accounting for the effects of premorbid functioning concerned clinical researchers for years. Barth et al. (1989) found a solution to these problems by using a test-retest design to assess collegiate football players before and after mild brain injury. The football arena offered a large number of potential participants who were likely to experience mild deceleration head trauma.

Barth et al.’s (1989) seminal study involving ten universities (n = 2350) found that those players who sustained a mild brain injury showed neurocognitive deficits at 24-hours post concussion and 5 days later, but recovered to better than preseason baseline and in line with controls by the 10th day. Consistent with other studies (e.g., Dikmen et al., 1986; Macciocchi, Barth,
Alves, Rimel, & Jane, 1996; McLean et al., 1983), these well motivated, young adults recovered rapidly from mild brain injuries. Largely because of the Barth et al. (1989) study, the sports arena was quickly recognized as a unique, relatively well-controlled laboratory for assessing mTBI. This study also set the methodological standard for baseline and serial neuropsychological testing, since then the study of athletes has proven to be a rich source of data regarding the effects of mTBI sustained on and off the field. The technique of using athletics as a model for understanding brain injury in general was termed, the Sports as a Laboratory Assessment Model (SLAM; Barth, Freeman, & Broshek, 2002).

Epidemiology of mTBI

Epidemiological studies indicate that 1 to 2 million new cases of mTBI are reported each year in the United States alone (Jennett & Frankowski, 1990; Thurman & Guerrero, 1997) and many more never come to the attention of health care professionals. Segalowitz and Lawson (1995) found that 30-37% of their sample of high school and university students sustained a mild brain injury. Subtle symptoms likely associated with concussion, such as sleep disturbance, social problems, and a variety of psychiatric diagnoses (e.g., attention deficits, depression, and reading, speech, and language disorders) were common. Given that millions of high school students participate in athletics each year, it is perhaps not surprising that approximately 300,000 of these mild brain injuries, or concussions, occur in sporting events. Gerberich, Priest, Boen, Staub, and Maxwell (1983) estimated that 200,000 concussions occur in high school football games each season. That would mean that 20% of all high school football players sustain at least one concussion each year. Almost half of the collegiate football players surveyed in 1989 reported having had a concussion by the time they reached college (e.g., Barth et al., 1989).

Studies often underestimate the incidence of mTBI because many patients do not present to hospitals or to health care professionals after suffering a mild concussion. Athletes in particular seem prone to underreporting their injuries in efforts to stay in the game; about 50% of cases of concussion across sports result in a referral to a health care professional (Powell & Barber-Foss, 1999). In football (63% of all sports-related injuries), tackling and being tackled appear to cause the most injuries (about 60%). Most sports show an increased risk of injury during games versus practice (wrestling is an exception) probably due to heightened intensity and motivation to win. There is evidence to suggest that the frequency of concussions is on the rise (Dick, 1997). The increase in size and speed of athletes and the consequent increase in force when making contact are likely contributors, but improved reporting methods may also help explain the rise.
Mechanisms of Mild Traumatic Brain Injury and Concussion

Mild concussion in sports usually occurs from rapid deceleration due to impact with stationary or opposing forces, which is translated on the brain as linear and/or rotational force. Newtonian physics can be used to describe these forces. Barth, Varney, Ruchinskastas, and Francis (1999) point out that, based on a formula originally used by Varney and Varney (1995), a football player running at 10 ft/sec will decelerate at a rate of 9.3 g after making contact with another player and stopping within 2 inches (formula: $a = \frac{v^2 - v_0^2}{2sg}$). Thus, assuming his head stops within a similar distance, the forces acting on his brain are 9.3 times that of its resting weight. An interaction of several factors including mass, weight, velocity, hardness and surface area of the impacting object predicts the extent of neuronal damage. Naunheim, Standeven, Richter, and Lewis (2000) used helmet-mounted accelerometers to measure the forces associated with contact to the head in soccer, football, and ice hockey. It appears that peak accelerations were greatest for soccer, but no recorded impact exceeded the acceleration level considered likely to produce significant neurocognitive sequelae.

The aforementioned forces may result in diffuse pathophysiological changes to the brain. Diffuse brain injury includes white matter and axonal stretching and shearing (termed Diffuse Axonal Injury, DAI), particularly when rotational forces are present. Axonal stretching in mTBI can result in swollen, beaded, and varicose fibers, which render neurons dysfunctional but not destroyed (Echemendia & Lovell, 2000). Like concussion, the severity of DAI is often graded from least severe (Grade I) to most severe (Grade III). In addition, parenchymal cytoarchitecture, particularly in the brainstem, can be disrupted by linear, tensile, or compressive strains. Though in rare cases of concussion axonal shearing can result in hemorrhage and subsequent coma, the vast majority of concussions fail to yield identifiable changes on CT or MRI. Thus, health care professionals tend to rely on neuropsychological assessment to identify brain dysfunction in these cases.

Neurochemical changes to the brain accompany the above mechanical changes immediately following mTBI (Wojtys et al., 1999). A commonly held view is that a neurochemical cascade creates cells that are vulnerable to dysfunction. In brief, an increased demand for glucose occurs with a concomitant reduction in cerebral blood flow (CBF). Excess glutamate is released and subsequent influxes of extracellular potassium inhibit the action potential (which likely accounts for the alterations of consciousness). A state of hyperglycolysis leads to rapid glucose loss, followed by decreased CBF and hypoglycolysis, which in turn leaves cells vulnerable or damaged. Interestingly, potassium might not reach suprathreshold levels for several seconds, which may explain the fact that some athletes make it to the sideline before collapsing from their injury (Maroon et al., 2000). The duration of decreased CBF seems to be critical in determining neurological outcome, as even brief interruptions in CBF can lead to ischemia and neurocognitive deficits.
Cholinergic pathways may also be at risk from concussion, as has been demonstrated in boxing (Jordan et al., 1997). The susceptibility to dysfunction of the hippocampus and related circuitry due to disruption of cholinergic pathways is well documented (Schmidt & Grady, 1995). Genetic factors are also likely involved. For example, Kutner, Erlanger, Tsai, Jordan, and Relkin (2000) found that older professional football players who possessed the APOE 4 allele scored lower on cognitive tests than did those without the allele. However, neurochemical outcome is likely predicated on a combination of factors such as age, APOE genotype, and/or cumulative exposure.

**Definition of Concussion and Injury Severity**

Initial definitions of concussion were so broad that they were not useful. In 1980, the definition was simplified to say that concussion was characterized by “immediate and transient post-traumatic impairment in neural function, such as alteration of consciousness, disturbance of vision, equilibrium, etc., due to brainstem involvement” (Maroon et al., 2000, p. 661). The authors proposed 3 grades of severity: Grade I- mild concussion with no LOC, Grade II- moderate concussion with LOC and recovery within 5 minutes, and Grade III- severe concussion with LOC lasting greater than 5 minutes.

In 1986, Cantu added post-traumatic amnesia to the list of mental changes in the definition of concussion. By 1991, Kelly et al. had developed what would become the Colorado Guidelines for the Management of Cerebral Concussion (CGMCC). The CGMCC criteria highlighted confusion in Grade I concussion and emphasized both confusion and post traumatic amnesia (PTA) in Grade II concussion. The latest American Academy of Neurology (AAN) definition and gradation system evolved from these guidelines and reflects the shift of LOC as a component of Grade II to LOC being the hallmark of Grade III concussion. Though consensus has not been forthcoming, concussion is now defined as any traumatically induced alteration in mental status that may or may not involve LOC (Quality Standards Subcommittee, AAN, 1997). Definitions and criteria continue to evolve as our understanding of concussion improves. Cantu is in the process of revising his guidelines based on the accumulated data (see Chapter 26 in this volume). The current gradations, emphasizing the presence of confusion and amnesia, are used to determine when a player is eligible to return to competition. Table 1.1 displays two common definitions of concussion and Table 1.2 displays the AAN’s return to play criteria.

It is clear that differing opinions about the relative importance of various diagnostic criteria still exist; at least 27 gradation systems have been proposed. The McGill group recently contended that because more than 75% of concussions incurred in sports do not involve LOC, a new grading system with 3 subdivisions of Grade I concussion is warranted. (Leclerc et al., 2001). Hinton-Bayre and Geffen (2002) found no relationship between the grade
of concussion (according to 3 commonly used grading systems) and level of neurocognitive impairment in rugby players. Such findings, coupled with the fact that none of the guidelines have been based on scientific data regarding the process of recovery, has lead some researchers to believe that current concussion management guidelines are inadequate for making return to play decisions (Collins, Lovell, & McKeag, 1999).

Player Protection and Return to Play Criteria

It has been almost a century since Theodore Roosevelt implemented important rule changes in football to protect players. Subsequent changes in tackling technique, and improvements in helmet design and padding likely have reduced the number and severity of injuries, but direct comparison is difficult. The speed and weight of football players have steadily increased, ostensibly raising the likelihood of injury. Though clinical neuroscience has had some
difficulty keeping up with this pace, a large body of knowledge regarding severity of brain injury, criteria for return to play, second impact syndrome, and sideline assessment has accumulated in the sports concussion literature. As a result, new injury prevention techniques (e.g., rule changes and better sport-specific equipment, education, and focus on skill acquisition) are being discussed and tested.

Determining if and when a player can return to competition is a critical decision with significant and perhaps catastrophic consequences. If a skilled player is held from play unnecessarily, his team may lose. More importantly, if he is allowed to return prematurely, he may suffer serious and possibly irreversible injury (see Second Impact Syndrome, this and subsequent chapters). While the importance of maintaining safety is obvious, many would argue that the pressure to win (and to return to play as soon as possible) is greater than it has ever been. Social and professional pressures and lack of controlled research have militated against the development and implementation of reliable methods for determining whether a player is ready to return to play. Despite this impediment, sports medicine researchers and team physicians have developed return to play criteria based on professional opinion and some level of consensus. Though the original attempts lacked uniformity and were based on little scientific evidence, most clinicians consider severity assessment the critical component of return to play criteria (Polin, Alves, & Jane, 1996).

Table 1.3. Cantu’s guidelines for return to play following concussion based on number and severity of concussions.

<table>
<thead>
<tr>
<th>Severity</th>
<th>1st Concussion</th>
<th>2nd Concussion</th>
<th>3rd Concussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I</td>
<td>Return if asymptomatic at exertion</td>
<td>Return in 2 weeks if asymptomatic for the past week</td>
<td>Terminate season; return next season if asymptomatic</td>
</tr>
<tr>
<td>Grade II</td>
<td>Return after asymptomatic for 7 days</td>
<td>Must sit out at least 30 days; may return if asymptomatic for 7 days; consider terminating season</td>
<td>Terminate season; return next season if asymptomatic</td>
</tr>
<tr>
<td>Grade III</td>
<td>Must sit out at least 30 days; then return when asymptomatic for 7 days</td>
<td>Terminate season; return next season if asymptomatic</td>
<td></td>
</tr>
</tbody>
</table>
Practical guidelines for return to play have been provided by Cantu (1986; 1991), Kelly et al., (1991) and the American Academy of Neurology (Quality Standards Subcommittee, 1997), among others. Each includes recommendations for return following one, two, or three successive injuries in a single season contingent upon the injury severity rating. For example, Cantu (1991) recommends that an athlete terminate participation for the season after three Grade I or two Grade III injuries (see Table 1.3). This is an outgrowth of Qui-gley’s Rule (Schneider, 1973), which stated that athletes should discontinue participation in sports following three cerebral concussions. The current criteria for safe return to same day play are (1) neurologic signs and symptoms clear within 15 minutes at rest and exertion, (2) neurologic exam is normal, and (3) no loss of consciousness (Cantu, 2001).

Multiple Concussions and Second Impact Syndrome

Recent evidence suggests that a history of concussion both increases the risk of sustaining a more severe concussion and decreases the threshold for sustaining a concussion of any severity in the future (Collins et al., 2002). This is significant because many athletes are at risk for concussion due to the nature of the sport, and their return to competition is often contingent on the number of concussions they have suffered.

The main reason that athletes must meet the aforementioned return to play criteria before returning to competition is that the brain appears to be incrementally vulnerable to subsequent trauma. The apparently rare but potentially devastating effect of successive mild concussions with resultant severe brain injury is termed, Second Impact Syndrome (SIS) and was first described by Schneider in 1973. The syndrome is said to occur when a second concussion is sustained before the signs and symptoms of the first have resolved. The circumstances surrounding the second concussion differ from the first only in its end result, which usually involves coma. Cantu and Voy (1995) estimate that SIS occurs in football one to two times per year but also occurs in other contact sports. Twenty-six SIS-related deaths have been confirmed since 1984 (Maroon et al., 2000). The mere possibility of SIS underscores the importance of reliable return to play criteria and neurocognitive assessment to be certain that full recovery has taken place.

Though the exact pathophysiology of SIS is poorly understood, available evidence suggests that the first impact results in subclinical edema and increased intracranial pressure (ICP), which make the brain susceptible to further injury. Significant ICP following the second impact impairs blood flow and causes severe tissue damage (“malignant cerebral edema”). Recent studies suggest that the reduction in blood flow is due to autoregulatory dysfunction and consequent vascular congestion (Alves & Polin, 1996). It appears that the vasoconstriction associated with Ca2+ influx near the site of injury is specifically responsible for the reduced blood flow (Wojtys et al., 1999).
Age may influence this change in brain physiology. Prins, Lee, Cheng, Becker, and Hovda (1996) found that immature rodents subjected to fluid percussion brain injury suffered more morphological and physiological damage than mature mice. However, there appears to be a critical maturational period during which the developing brain is most vulnerable. Insults before or after this period may yield relatively less damage. Though this time frame is unclear in humans, it may be that the period of vulnerability predisposes the brain to catastrophic injury when subjected to repeated concussions. This might explain the apparent increased risk of SIS in adolescent young adults.

SIS remains an indistinct and poorly understood diagnostic entity and some researchers question its existence. For example, at least one attempt to provide diagnostic criteria (Definite, Probable, or Possible SIS) based on clinicopathophysiologic features failed to identify any of 17 cases as Definite SIS (McCrory & Berkovic, 1998). In 12 of the cases, even the possibility of SIS was ruled out. More can be found on this intriguing issue in subsequent chapters of this volume.

Sideline Assessment of Concussion

Quick and accurate evaluation of mental status on the field and on the sideline is one of the most challenging problems faced by team physicians and trainers. Interruptions, distractions, confined space, and a very limited time frame are just some of the problems faced by the player and the examiner. The highly heterogeneous nature of concussion further complicates assessment and diagnosis. The assessments require a well-formulated plan that can be implemented quickly and routinely in order to be effective.

On the field, the injured player undergoes “ABC assessment” (patent Airway, regular Breathing, normal blood Circulation/pulse) and a brief mental status exam. Questions such as those proposed by Maddocks, Dicker, and Saling (1995) appear to discriminate concussed from non-concussed players better than standard orientation questions, and can be started on the field. Once off the field of play, the player undergoes a more comprehensive evaluation, including a neuropsychological exam. The Standardized Assessment of Concussion (SAC; McCrea et al., 1998) is the first very brief, yet systematic empirically based, and validated assessment tool for sideline evaluations. It includes brief tests of orientation, attention, and memory and is used in conjunction with a brief neurologic exam or neurologic checklist (e.g., Sideline Concussion Checklist, Kutner & Barth, 1998) to determine the extent of neurologic/cognitive compromise (as a gross screening), the need to cease competition, and the necessity of further monitoring. The SAC now has 3 equivalent alternate forms (McCrea, 2001) and despite its vulnerability to practice and ceiling effects, it is clearly the best sideline assessment available at this time.
Neuropsychological Evaluation of the Athlete

Barth et al. (1989) are credited with establishing the standard for assessment of amateur athletes. The beginnings of neurocognitive assessment in the professional ranks are less clear but appear to have begun in boxing. Researchers looked to boxing as a model of brain injury because it is the only major sport in which the goal is to “inflict brain damage, cause a concussion or render the opponent unconscious” (Jordan et al., 1997, p. 453). Since Martland’s (1928) paper on the “punch drunk” syndrome, a body of literature has accumulated on the effects of the multiple relatively low-energy blows characteristic of some boxing injuries. Neurological and neuropsychological investigations have documented acute and persistent deficits in boxers who have experienced knockouts or subsequent blows to the head (Casson et al., 1984; Jordan et al., 1997; McLatchie et al. 1987; Roberts, 1969). Although the literature suggests that impairment is fairly prominent, the results of many of the investigations have been inconsistent, primarily due to methodological problems (e.g., small sample sizes, inappropriate controls, etc.).

Mark Lovell recognized that similar injuries were likely to occur in the National Football League (NFL). With the Pittsburgh Steelers, he established the first clinically oriented program aimed at facilitating decision-making for return to play following a concussion. A brief yet broad-ranging battery is administered to each player at preseason and again in the event of a concussion.

Several league-wide neuropsychological testing programs have now been established at both the collegiate and professional levels. Lovell’s work with the Pittsburgh Steelers Organization has expanded to involve neuropsychological assessment of over 1,500 professional football players representing numerous National Football League teams. Ruben Echemendia developed a multi-sport neuropsychological testing program at Penn State University involving hundreds of athletes from football, men’s and women’s soccer, men’s ice hockey, men’s and women’s basketball, wrestling, and women’s lacrosse. Lovell and Echemendia have also established a similar league-wide neuropsychological testing program with the National Hockey League. A network of neuropsychologists across North America allows players to be evaluated in any city in which they play.

In addition to other innovative neuropsychological studies with football players (e.g., Collins, Grindel et al. 1999; Lovell & Collins, 1998; Olesniewicz, Sallis, Jones, & Copp, 1997), neuropsychological investigations have been conducted in amateur and professional soccer (Abreau, Templar, Schuyler, & Hutchison, 1990; Matser, Kessels, Lezak, Jordan, & Troost, 1999), rugby, (Hinton-Bayre, Geffen, & McFarland, 1997), ice hockey, (Lovell & Collins, 2001; Tegner & Lorentzon, 1991), and equestrian sports (Bailes, 1999; for a current review see Broshek, this volume). Epidemiological data regarding concussion and brain injury are available for cycling (Noakes, 1995), winter sports (Prall, Winston, & Brennan, 1995), and golf.
(McGuffie, Fitzpatrick, & Hall, 1998). Formal study of concussion in these sports is forthcoming.

Soccer has received increased media attention in large part due to reports of risk of injury when heading the ball (Babbs, 2000; Matser, Kessels, Lezak, Jordan & Troost, 1999). It is critical to note that important factors such as the frequency of heading another player’s head, hitting the goal post, making contact with the ground, and body-to-body contact were seldom controlled in early studies. Grote and Donders (2000) add that many studies were poorly controlled demographically (e.g., some participants were heavy alcohol users) and in some cases conventional testing procedures were not used. Nevertheless, concussions do occur in soccer. Delaney, Lacroix, Leclerc, and Johnston (2002) found that nearly 63% of soccer players in their one-season survey reported symptoms of concussion. To date, the evidence for frank neurocognitive impairment from heading alone is equivocal and well-controlled research on this matter is still required to draw appropriate conclusions.

Social Forces in Sports Neuropsychology

Professional sports is a multibillion dollar industry. College sports often generate more money for their academic institutions than any other single branch of the school. Shulman and Bowen (2001) describe three factors that account for the rising interest in sports in this country. The first of these is the growth of the United States’ entertainment-driven economy and the commercialization of athletics, which has resulted in huge financial incentives for athletic organizations to produce winning teams. This has been especially transforming for collegiate athletics departments, which have become increasingly influential within academic institutions.

The second factor involves the heightened competitiveness of college admissions. Career advancement in our knowledge-based economy has amplified the importance of a college education, particularly from institutions with impressive reputations. As a result, admissions offices have become more interested in candidates with distinctive qualifications and talents and thus “...introduced onto the college campus a group of athletes who are as specialized in their own ways as the most intensely focused computer scientists.” (Shulman & Bowen, 2001, p. 23). Third, the increased competence and specialization of pre-college athletic talent coupled with the firm institutionalization of sports at the collegiate level, has raised the bar for pre-collegiate athletic competition, with a focus on greater specialization at younger and younger ages. The World Health Organization, and the International Federation of Sports Medicine, have shown concern about these trends, stating in 1998 that, “There is growing evidence that excessive...and intensive training may increase the rate of [player] overuse and catastrophic injuries.” (p. 446).
Computerized Assessment in Sports Neuropsychology

It appears that much of neuropsychology’s future promise lies with computerized assessment. Computerized testing allows the examiner to assess common sequelae of concussion, including subtle changes in processing speed to the millisecond. Computers also reduce the impact of practice effects by providing multiple equivalent forms of the test. The Automated Neuropsychological Assessment Metrics (ANAM) was introduced to address this issue. The number of alternate forms is almost infinite and it can be configured to assess a specific neurocognitive domain or several domains (Koffler, 1999). Early data on the ANAM indicate that it measures constructs also measured by common traditional neuropsychological tests that are sensitive to brain injury: Cognitive processing speed, resistance to interference, and working memory (Bleiberg, Kane, Reeves, Garmoe, & Halpern, 2000).

At least two other computer-administered measures are being validated in this country. First, the Immediate Measurement of Performance and Cognitive Testing (IMPACT; Maroon et al., 2000) was recently developed for athletes in particular. Cognitive domains including reaction time and a range of attentional and memory skills are assessed. There are three forms, and like the ANAM, the alternate forms can be combined in many ways to reduce practice effects. A post-concussion scale is included to provide self-report data regarding common signs and symptoms of concussion (e.g., headache, nausea, drowsiness, etc.).

Second, the Concussion Resolution Index (CRI, Headminder), an internet-based measure of cognitive functioning, was developed by David Erlanger and colleagues (2001) to help determine when a player can return to play. It records both simple and complex reaction time, attention, memory, and cognitive processing speed. The initial validation showed (1) that the CRI is very sensitive to reduced cognitive efficiency following concussion (88% of concussed athletes were detected) and (2) that the cognitive tests of the CRI improve detection of symptoms over self-report by 25% at the second follow-up (Erlanger et al., 2001). Because it is web-based, the CRI is accessible to health care officials in remote locations (e.g., when traveling to “away” games), which is particularly appealing for teams who travel regularly. Other important advances in computerized assessment are discussed in the Special Issues section of this volume.

Future Directions of Sports Neuropsychology

Sports neuropsychology also seems well positioned to take advantage of advances in biotechnology. The potential benefit of using a mouthpiece to reduce translational forces in head injury has already been discussed (Barth, Freeman, & Winters, 2000; Winters, 2001). It may be possible in the near future to transmit specific telemetry data to the sideline to help determine the
forces that occur in head trauma at the moment of impact. Advances in helmet composition, shape, and padding are also being made. Accelerometers have shown promise in helmet design and development by documenting forces and levels of dissipation based on helmet shape. Mechanical limits on the degree to which the head is free to move (e.g., neck braces) are also under investigation.

Use of laboratory tests on the sideline is promising. For example, assessment of blood oxygen levels could provide immediate information regarding oxygen saturation and glucose utilization. The continued investigation of genetic testing is also needed to clarify the relationship between APOE4 and concussion and dementia. Other genes involved in neurodegenerative processes will likely require attention as well.

Further explication of the symptom constellation of concussion as well as the particular combinations of clinical features that best predict injury severity are warranted. It is not unusual for players to complain of persistent headache or “being in a fog,” yet perform at or above baseline levels on neuropsychological tests. Moreover, concussions present in numerous ways despite apparently highly similar injury characteristics. This suggests that there may be more than one type of concussion, that some individuals are at increased risk premorbidly, and that different batteries of tests may be needed. The roles of such factors as age, education, learning disability, history of concussion, intellectual level, psychosocial functioning, and general physical health in recovery from concussion require further examination (Barth, Diamond, & Errico, 1996; Collins et al., 1999).

More research like that of McCrea et al. (2002) documenting the slope of early recovery from concussion is needed, as it will likely have important implications for return to play decisions. Researchers must also find ways to streamline existing measures while maintaining the clinical utility.

Finally, special attention to education and prevention of concussion in all sports is warranted. Although not yet proven, it is reasonable to expect that children experience more severe DAI (shearing from rotational forces) and coup-contracoup injuries, given their immature frames and musculature. This underscores the importance of education in youth sports. Education can also help athletes of all ages be more forthcoming about their injuries. Currently, it is still considered a sign of toughness to “stick it out” despite injury and this message is conveyed to young athletes. This may be especially common for concussion because it can be less obvious to observers.

Summary and Recommendations

The commercialization of athletics and the resultant increase in media attention given to famous athletes, including those who have sustained multiple concussions, has generated increased awareness of the potential seriousness of mild brain injury. Physicians and athletic trainers in sports medicine have
turned to the clinical and scientific literature for guidance regarding sideline medical assessment, whether children should “head” soccer balls, or when an athletic career should be retired after multiple concussions. The realm of athletic competition facilitates access to an at-risk population, baseline testing and testing shortly after injury, and straightforward follow up (McCrea et al., 2002). Because of our increasing awareness and research in sports concussion, significant rule changes have been made, particularly in football. However, continued change is necessary. Proper techniques should be taught by coaches at all levels. Cantu and Mueller (2000) recommend that emphasis be put on conditioning and fitness of the head and neck on proper fitting equipment, and on properly trained on-field personnel in case of catastrophic injury. The primary goal is to ensure player safety during athletic competition. By using the playing field as a lab, neuropsychology has helped formulate return to play criteria, severity ratings, recovery curves, and other tactics. As a discipline, it is ideally suited to continue advancing this goal.

References


References


energy of the head during impact. The rate of change of kinetic energy is what is more commonly known as power. An equation describing the rate of change of energy of the head, for both forms of motion is of the form

\[
HIP = ma_x a_x dt + ma_y a_y dt + ma_z a_z dt + I_x \alpha_x \alpha_x dt + I_y \alpha_y \alpha_y dt + I_z \alpha_z \alpha_z dt
\]

where HIP is the head impact power, \( m \) is the mass of the head and the \( I_s \) are the mass moments of inertia of the head about the respective axes. The probability of concussion as a function of HIP has been determined. On the basis of this data, a 50% chance of a concussion occurs if the change of kinetic energy of the head reaches about 12.7kW. A concussion is almost a certainty if the power level reaches 25kW.

Currently, additional MTBI data are being collected and it is anticipated that the HIP will be extended to become a MTBI Index. The Power Index will take a form similar to that above but will include coefficients that both non-dimensionalize the function and include parameters that directly reflect the differences in brain injury tolerance associated with skull movement in different directions.

Summary

Head injury tolerances to impact have been described in terms of the motion of a rigid headform representing the human head. Various functional relationships between the head acceleration and head injury severity have been reviewed. None of the measures relates to a specific injury mechanism or type. They relate only to the severity of closed brain injury associated with rigid skull motion. Research continues to seek a functional relationship between the severity or probability of such brain injury and the detailed manner by which the head moves upon impact.

References


which may persist a week or longer. Calcium influx occurs early and recovers more rapidly, usually over several days. Axonal injury may be immediate, but delayed secondary axotomy has been reported weeks after injury in humans. Persistent dysfunction in excitatory and inhibitory neurotransmission is a potential mechanism for chronic cognitive and neurobehavioral symptoms following brain concussion. Current guidelines for return to play only upon resolution of all neurocognitive deficits are a good starting point, but more precise time-windows may be elucidated with increasing understanding of and improved ability to monitor specific derangements such as cerebral glucose metabolism, regional brain activation, and neurotransmitter levels.

Repeated injury may magnify reversible neurometabolic abnormalities to the point of permanent cellular degeneration. In some cases, repeated injury may consist of premature activation of injured neurons in the absence of trauma. Also, cerebral responsiveness may be diminished in the post-injury period, raising the risk of an early return to normal play by increasing the likelihood of injury recurrence.

Finally, traumatic injury to the immature brain should be taken seriously, despite the apparent resiliency of youth. Diffuse biomechanical cerebral injury may disrupt normal developmental neural pathways and impair experience-dependent plasticity, with a resultant loss of cognitive potential. Additionally, the developing brain may be uniquely vulnerable to alterations in metabolism, connectivity and neurotransmission but may only manifest deficits with time; therefore, injured children should be closely monitored for the later appearance of behavioral and intellectual difficulties.

Acknowledgements

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Figures 4.1–4.4 are reprinted from R.C. Canta, Neurologic Athlete Head and Spine Injuries, 2000, with permission from Elsevier.

Figures 4.5 and 4.6 are taken from Osteen et al., Journal of Neurotrauma, 2001, and Fineman et al., Journal of Neurotrauma, 2000, respectively, with permission from Mary Ann Liebert Publishing.

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Discussion

Several pathophysiological cascades are initiated at the time of a traumatic event to the brain. Among the vast array of pathological consequences amyloid deposition, NFT formation, and disruption of central cholinergic transmission are essential in understanding the potential genetic contributions to outcome after TBI. Evidence suggests that APOE genotype influences the outcome of TBI via several interrelated mechanisms. It is hypothesized that the following factors are involved in the pathophysiology of CTBI. During impact depolarization following TBI there is an increased release of glutamate and ACH which exerts differential effects on neurobiological function. Increases in glutamate results in increased calcium influx and increased intracellular calcium. This increased intracellular calcium then activates proteases, produces energy failure, and impairs cytoskeletal function. This impaired cytoskeletal impairment results in axonal injury and subsequent interruption of axonal transport in areas rich in cholinergic function. This impairment of axonal transport and increased intracellular calcium increases tau hyperphosphorylation and the formation of NFT. Increased release of ACH secondary to impact depolarization along with cytokines IL-1 and IL-6, and possibly other factors results in the upregulation of APP. This in a setting of impaired axonal transport leads to increased intraneuronal accumulation of APP (a marker of axonal injury). Activated proteases (e.g. ? calpains) and /or other factors yet to be determined result in the abnormal processing of APP, thus initiating amyloid deposition. Thus amyloid deposition and NFT formation are associated with reduced cholinergic function, which is then responsible for the cognitive impairment encountered in CTBI. These above mentioned factors produce an Alzheimer’s-like disease process, which is influenced by APOE genotype, therefore providing a genetic predisposition.

Conclusion

In view of the clinical data suggesting a possible genetic influence on neurological outcome after TBI, further investigation utilizing larger well-defined athletic populations is indicated, before genotyping could be utilized to protect the neurological well being of the athlete. Furthermore, the neurobiological functions of APOE and the associations between CTBI and AD need to be further explored.

References


ing which further underscores the need for conservative management in the high school concussed athlete.

Summary

This chapter has provided an overview of neuropsychological assessment within the college and high school environments. We are pleased to report that work with college and high school athletes is currently an area of considerable activity and numerous clinical and research programs have been established at both levels. Within the next five years, we expect continued growth in interest in concussion in these athletes and are confident that this research will lead to substantial innovations regarding diagnosis, management, and treatment of concussion.

References


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nerability (as demonstrated across these studies), as well as under conditions of increased task challenge with potentially devastating consequences, such as in the context of school and university examinations. Finally, increased risk of dementia in association with repetitive sports-related head injury is a potentially dire consequence that needs to be factored in.

Thus, ethical issues around the participation of minors in a sport such as Rugby Union needs to be seriously addressed. This is particularly so for those whose cerebral reserve is already compromised due to prior learning disability or neurological disorder. As a start it would appear imperative to discourage any compulsory or routine participation in the sport, especially in the case of children and adolescents. Rather, participation should occur only following properly informed consent in which the potential for insidious brain-related consequences in association with the game are fully acknowledged. Further, screening procedures should be in place in order (i) to identify vulnerable players such as those with prior compromised cognitive function, (ii) to monitor those playing in the more hazardous forward positions, and (iii) to guide return-to-play decision for those who are concussed. Generally, as indicated in relation to the wider spectrum of contact sports (Maroon et al., 2000; Shuttleworth-Edwards & Border, 2002; Woijtys et al., 1999), it would appear essential to involve neuropsychologists in the management of concussion in Rugby Union, for both educative and screening purposes.

References


effective implementation of neuropsychological assessment in the management of concussion.

References


Summary

Close observation and reliable neuropsychological assessment of the brain injured soccer player is critical to the prevention of a more serious injury and potential cumulative neuropsychological impairment. As highlighted by this chapter, the sport of soccer is currently undergoing significant research scrutiny regarding the issue of concussion and it is likely that this area of research will continue to expand over the next decade. Ultimately, it is hope that current research that is underway with college and professional athletes will have an impact on the care of the younger athlete and will result in practical strategies for increasing the safety of younger athletes throughout the world.

References


sports. Currently, approximately one-half of NFL teams are using computer-based testing (e.g. ImPACT) and this trend is likely to continue in the future. Various approaches to computer-based neuropsychological assessment are described elsewhere in this text and therefore will not be reviewed here (see Chapter 20).

Summary

This chapter has reviewed the potential uses of neuropsychological testing with professional athletes and has reviewed current research in the area. The current large-scale program being conducted with the NFL has been reviewed. The use of neuropsychological testing has evolved rapidly from being virtually unheard of in the early 1990s to widespread current acceptance. In fact, neuropsychologist’s have gradually become accepted valued team members in many NFL franchises and this trend promises to continue as team medical staff continue to seek better methods of making return to play decisions. As the NFL program began in response to pressing clinical issues, the research potential of this project has yet to develop fully. We anticipate that research in this area will increase rapidly over the next five years-leading to exciting new discoveries regarding recovery from mTBI.

References


agement guidelines. More specifically, large-scale projects such as the NHL concussion program hopefully will eventually yield evidence-based concussion strategies, which are based on a number of factors including the results of neuropsychological testing.

Additionally, the NHL concussion project will promote a better understanding of the role of neuropsychological testing in the assessment of athletes. The project will specifically answer questions such as: 1) which neuropsychological tests are sufficiently reliable and valid to allow their continued and more widespread use throughout organized athletics? What neuropsychological cutoff scores should be utilized in making return to play decisions and what confidence intervals will be utilized? and; 3) to what extent do players’ self-report symptoms correlate with objective neuropsychological test results. As is detailed in Chapter 18 of this volume, the correlation between neuropsychological test results and athlete symptoms self-report is an imperfect one. This dissociation between symptoms and neuropsychological performance may be a function of a variety of factors, which include the involvement of both neurological and non-neurological processes (e.g. brain vs. vestibular systems), limitations of current testing or other processes. Hopefully, the NHL project will help to answer some of these questions in the future.

Summary

This chapter has provided a summary of the NHL concussion program and has focused on important issues regarding the evaluation and management of the concussed hockey player. Given the preliminary nature of this project, a clinical rather than a research perspective has been presented and issues important to clinical decision-making have been discussed. It is hoped that the NHL concussion program will result in a decrease in sport-related concussions and to a better understanding of sports-related concussion. It is also hoped that this project and other like it will promote better evaluation and management strategies for amateur athletes. As noted throughout this chapter, the neuropsychologist has come to play an increasingly important role in clinical decision-making within professional hockey. It is anticipated that this role will continue to evolve over the next decade and beyond.

References


concussive head blows. It is unlikely that in most cases, a single boxing bout will lead to irreversible and permanent brain damage. However, analysis of relevant factors such as the number and frequency of head blows and velocity of punches may help to gain a clearer understanding of whether or not there is a critical number of fights, knockouts, or punches which compromise a boxer’s cognitive reserve.

There is great debate in the medical community regarding whether boxing should be banned. We recommend that the data obtained from neuropsychological studies on boxers be used to improve safety standards in the sport. Medical requirements for boxers set forth by the various boxing commissions vary a great deal from state to state. In New York, probably the strictest state in terms of medical requirements for active professionals, boxers must undergo serial CT scans, an EEG, and a neurologic exam in order to maintain their license. Given that neuropsychological testing has been shown to be sensitive to sports-related head injuries in cases where other medical exams (i.e., neuroimaging and neurologic exam) are unremarkable, serial assessments would serve as an objective measure to monitor changes in cognitive status throughout a boxer’s career. Systematic monitoring of cognition in boxers would allow for appropriate interventions before significant and irreversible neurologic dysfunction becomes a reality.

Acknowledgement

Tables 14.1–14.3 are taken from B. Jordan (Ed.), Medical Aspects of Boxing, with permission from CRC-Press.

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this tentative conclusion may be erroneous, the burden is on researchers to
design and implement studies that provide interpretable and defensible data
to the contrary. Studies with flawed methodology only complicate an already
complex clinical and research problem. For example, most researchers are
appropriately cautious when interpreting data, and criticizing one’s own
methodology is obligatory, but all too often researchers do not take their self
criticism seriously. For example, in the soccer study cited earlier, the authors
generally minimized threats to validity and concluded that soccer presents
a “medical and public health concern” (Matser et al., 1999, p. 973). While
their conclusion may in fact be accurate, a more adequately designed and
executed study would certainly be more persuasive and helpful in addressing
the concerns they express.

We have presented a number of issues relevant for designing and imple-
menting studies of concussion (see Table 16.3). We intentionally avoided dis-
cussing specific measures or test batteries since this topic has been addressed
in other chapters. We also avoided proposing specific designs, but we do
recommend prospective pretest-posttest comparison group methodology
unless randomized designs can be employed. In addition, established multi-
ple assessment preinjury test baselines and reliable change estimates appear
quite promising. Despite our attempt to address many of the problems facing
researchers, there are other issues that arise from time to time depending upon
the type of research being conducted. Most importantly, many issues remain
to be investigated. First, we need to establish reliable and valid severity indices
for concussions. Second, the neuropsychological consequences of single and
multiple concussions must be firmly established and then the results should
be replicated. Third, the short and long-term morbidity related to concussive
injuries requires attention. Finally, models of concussion prevention need to
be investigated. Unfortunately, none of the aforementioned issues are easily
researched, but investigators would benefit from focusing on methodology
as a primary consideration in all empirical efforts. In the final analysis, there
is nothing more comforting than a reliable and valid scientific finding that
stands the test of time.

References


field Publishing.


These methodological limitations are not unique to this study, of course. Many apply to the majority of studies relating to reliable change. They are mentioned here, as a means of summarizing what has been discussed in this chapter, to encourage advancements in the methodologies as applied to sports neuropsychology.

The measurement of change is a complex undertaking that is receiving increasing attention in both the clinical and experimental literature. The fact that it had historically received scant attention despite almost universal recognition of its challenge is an index of the difficulties involved. Sports neuropsychologists involved with sideline and return-to-play evaluations cannot ignore these issues. Many of the issues are shared with the field of measurement of change in general, although some issues are unique to athletes and situational demands. This area of research eventually will provide essential information to advance the clinical practice of evaluating athletes following concussions.

References


scores for baseline performances that fall in the average range are more evenly distributed.

- It is important to avoid over-interpreting or over-pathologizing neuropsychological test scores. Be careful not to inadvertently make the impact of the injury worse for the athlete. It is common to have concerns about “brain damage.” Athletes who focus, dwell, and worry about their symptoms are at increased risk for protracted recovery patterns.

- Of course, it is also important not to minimize concussions. These injuries, unlike orthopedic injuries, cannot be seen. There is a tendency on the part of coaches, trainers, and athletes to ignore or minimize the injury. Thus, the sports neuropsychologist must consider carefully whether response bias might be affecting an athlete’s symptom reporting.

- There is very little research evidence to support the notion that we can detect changes on neuropsychological tests that are directly attributable to the effects of a concussion after three months post injury. This is because most of these injuries have resolved, at least functionally, before then. Moreover, neuropsychological tests, with their inherent measurement error and situational influences, typically are not sensitive to subtle medium-term effects from these injuries. Baseline, pre-injury testing increases the likelihood that the neuropsychologist will make valid and accurate inferences regarding test performances derived from evaluations occurring after the typical recovery period. The absence of pre-injury data increases the likelihood of interpreting natural variability in test scores as injury-related, or of misunderstanding premorbid abilities levels and thus misinterpreting post-injury test scores.

Considerable research is needed to enhance the reliability, validity, and accuracy of serial assessments with athletes. At present, this is largely a clinical process that is poorly informed with empirical data. In due course, because of the unique applications of neuropsychology with athletes, we predict that advancements in sports neuropsychology will be used to inform clinical practice in mainstream neuropsychology.

References


spite of challenges, the launching of two large-scale professional head injury studies providing pre and post information on concussion will provide valuable data not only for sports but also for the general population.

References

are highly cost-effective, especially relative to the costs incurred with face-to-face, paper-and-pencil testing. Computers are becoming more and more common at all levels of athletic competition, thus making them much more readily available to an ever-growing number of athletes. This is particularly relevant at the high school level where finding the funds for a concussion safety program is difficult. Computerized assessment has allowed many high school programs to participate in sport-concussion safety programs, which they would not have been able to afford if they had to depend upon paper-and-pencil testing.

The computerized assessment techniques described within this chapter have been shown to play a very critical role in helping to make return-to-play decisions following a concussion. It is clear, however, that at this point in time, there continues to be a place for traditional neuropsychological testing in working with athletes. In fact, some authors have advocated combining computerized assessment programs with traditional paper-and-pencil testing (see Echemendia & Julian, 2001) for assessing sports-related concussions. Moreover, athletes that have a prolonged post-concussive disorder may require a more extensive neuropsychological evaluation using more lengthy and detailed procedures. Yet it is important to recognize that traditional paper-and-pencil neuropsychological testing can no longer be the sole method used to assess large group of athletes in a time and cost-effective manner.

Summary

Assessment of sports-related concussion is critical in the medical management and good health of athletes. Sports-related concussion assessment has thrust neuropsychology to the forefront of this area of health-care in that neuropsychological assessments are considered a cornerstone in detecting the effects of concussions and an integral part of making return-to-play decisions (Aubry et al., 2001). Research over the past few decades has consistently demonstrated that variable and slowed reaction time is particularly sensitive to the effects of concussion. The advent of new computerized programs designed to assess reaction time, working memory, speed of information processing, and anterograde memory have demonstrated good sensitivity in detecting concussions and are being used to assist physicians and athletic trainers make better return-to-play decisions, while helping to ensure the health and safety of athletes.

References


factors associated with pathophysiology (Hovda, Chapter 4 in this volume) and neuropsychology (Macciocchi & Barth, Chapter 16 in this volume) in the recovery process. When such biological factors are juxtaposed with the role of personality factors (e.g., Ruff et al, 1996) and coping style (e.g., Godfrey, Knight, & Partridge, 1996) as outcome determinants, the potential interactions are staggering. On the other hand, wonderful opportunities and challenges for exploring the mind-body question are presented. The role of psychotherapy and its influence in this system is one such question.

References


For example, is the “athletic culture” universal or does it vary by country of origin or by sport? Are there “cultural” differences between soccer, ice hockey, rugby, figure skating, etc.? These possibilities create many avenues for exciting research but also serve to keep us mindful of the many influences and sources of variation in our data.

Conclusion

Cultural differences in sports present a new challenge to neuropsychology because of the ethnic, national, and linguistic differences that exist among athletes. The complexity of assessing these athletes may be daunting and the solutions presented in this chapter are not fully satisfying. We face challenges with respect to linguistic differences, inadequate test and norm development, cultural differences related to views of medical personnel, as well as the possibility of an “athletic culture” or sport-specific culture. As a young science, there is more that we do not know than we know. Our task is to build on what we know while being forthright about the limitations of our knowledge. At present we cannot capture or explain a sizable proportion of the variance in our tests that is a function of cultural differences. However, through careful reading of the research literature, constant consultation with each other and other cultural “experts”, we can begin to explain more of the variance and become a valuable resource for safely returning an athlete to competition.

References


References


your role to all parties, establish good working relationships with the team physician and team athletic trainers, and as is the case with most questions of ethics – When in doubt, Consult!

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