Is Soccer Bad for Children's Heads?: Summary of the IOM Workshop on Neuropsychological Consequences of Head Impact in Youth Soccer

Margie Patlak and Janet E. Joy, Board on Neuroscience and Behavioral Health

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Summary of the IOM Workshop on Neuropsychological Consequences of Head Impact in Youth Soccer

Prepared by Margie Patlak and Janet E. Joy

Board on Neuroscience and Behavioral Health

INSTITUTE OF MEDICINE

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The serpent has been a symbol of long life, healing, and knowledge among almost all cultures and religions since the beginning of recorded history. The serpent adopted as a logotype by the Institute of Medicine is a relief carving from ancient Greece, now held by the Staatliche Museen in Berlin.

"Knowing is not enough; we must apply.
Willing is not enough; we must do."
—Goethe

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We also thank each of the workshop speakers for their thoughtful, informative, and lively presentations. Their work has been and will continue to be instrumental in protecting our children's futures by promoting safe sports policies. We extend special appreciation to the workshop chairs, Linda Cowan and Michael Johnston, for keeping the lively discussions focused and moving forward throughout the day. Many of the workshop participants responded frequently and faithfully to the fact-checking inquiries we sent during the preparation of the summary of the workshops, and we especially thank Jon Almquist, Trey Crisco, Ruben Echemendia, Kevin Guskiewicz, Albert Hergenroeder, David Hovda, James Kelly, Don Kirkendall, and Muriel Lezak for helping sort out the details.

This project would not have been completed without the excellent and much-appreciated assistance of the Institute of Medicine staff. Amanda Hunt and John Rockwell did much of the background research for the project. Brian McQuillan was the White Knight who stepped in at the last minute to do a terrific job of handling the meeting logistics.

REVIEWERS

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

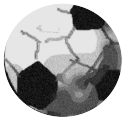
Julie Gilchrist, M.D., National Center for Injury Prevention and Control, Centers for Disease Control, Atlanta, Georgia

Stephen H. Hauser, M.D., Department of Neurology, University of California at San Francisco, San Francisco, California

Mark R. Lovell, M.D., Department of Orthopedic Surgery, University of Pittsburgh, Pittsburgh, Pennsylvania

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the final draft of the report before its release. The review of this report was overseen by Richard Frank, Harvard Medical School. Appointed by the National Research Council and Institute of Medicine, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authors and the institution.

CONTENTS



INTRODUCTION

During a game, a high school football player suffers a blow to his head without being knocked unconscious. Although he has a persistent headache and other symptoms of a concussion, he continues to go to practices and pushes himself to participate in a game just a week later. During that game he is struck in the head again. Two plays later he collapses on the field, and less than a day later he dies.

Although it may sound too incredible to be a true story, it is. Fortunately, such deaths from sports concussions rarely occur, and this is a worst case scenario. But sports concussions are in fact far more serious than most people realize. There are many more examples of former A students struggling to pass high school after experiencing concussions on the soccer or football field. Many student athletes have been forced to abandon both their sports and their career aspirations because they never fully recovered from concussions.

These disturbing examples counter the common belief that a concussion is just a bump on the head with no lasting effects. Indeed, recent research reveals that a concussion unleashes a cascade of reactions in the brain that can last for weeks, and make it particularly vulnerable to damage from an additional concussion.

There is also evidence that youths who experience concussions may be at more risk for brain damage than adults because their brains are still developing and have unique features that heighten their susceptibility to serious consequences from head injuries.

Even though people generally think of soccer as a safer sport than football, soccer players experience concussions about as often as football players. Concussions are usually caused by head collisions with players, goalposts, or the ground. Soccer players also frequently use their unprotected heads to pass or shoot the ball. A soccer ball can hit the head with significant force, and there has been considerable debate over whether such "heading" also fosters brain injury.

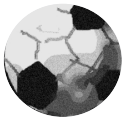
Soccer is probably the most rapidly growing team sport in this country, especially for girls and women. Millions of children and adolescents participate in youth soccer leagues and there are hundreds of thousands of adolescents on high school soccer teams. The growing popularity of soccer among youths combined with reports in the medical literature that soccer players may be at increased risk for brain injury has fostered concern that children who play soccer may not be adequately protected from head injury.

To explore whether soccer playing puts youths at risk for lasting brain damage, the Institute of Medicine brought together experts in head injury, sports medicine, pediatrics, and bioengineering. In a workshop entitled "Youth Soccer: Neuropsychological Consequences of Head Impact in Sports," that was held in Washington D.C. on October 12, 2001, these experts presented the scientific evidence for long-term consequences of head injury from youth sports, especially soccer, possible approaches to reduce the risks, and policy issues raised by the subject. Workshop presenters were asked to:

- explore the scope of the scientific evidence regarding repetitive head injury in players,
- assess the special considerations for such injuries for youths by reviewing the role of development on vulnerability, and
- to identify the policy issues relevant to head injuries in youth sports.

Some of the findings presented by the speakers raised concerns, such as the high concussion rate of high school soccer players, the frequent persistence of impaired brain functions even after other symptoms of a concussion disappear, and the need for a better understanding of when it is safe for players to resume playing after they have had a concussion. But other findings were reassuring, such as studies that suggest that with the type of soccer balls used in the United States, heading is not likely to cause brain injury in youths, nor is playing soccer likely to cause permanent brain damage.

This is a summary of the reports from these experts in the field, and the lively discussions that followed them. Topics covered include: causes of head injuries in soccer; how to detect a concussion; the biology of concussion; studies of soccer and football players; the role of protective headgear; and policy implications, such as how to decide when a concussed player should be allowed to return to the playing field.



CAUSES OF HEAD INJURIES IN SOCCER

Several of the speakers talked about what is likely and not likely to cause head injuries in soccer. Sports medicine expert and former soccer player Dr. Donald Kirkendall delved into whether repetitive heading might cause brain injury. He said that if the heading was being done properly, the ball's impact with the head is not usually forceful enough to cause a concussion. Proper heading involves contracting the neck muscles so the head is more rigidly fixed to the trunk of the body and hitting the ball squarely with the forehead near the hairline.

Although soccer balls can be kicked to speeds as high as 70 miles per hour, even most professional players cannot kick a ball that fast and most soccer players would not attempt to head a ball moving that fast, Dr. Kirkendall said. He also added that youths rarely have enough force to kick a ball to speeds higher than 40 miles per hour. He calculated the impact of a soccer ball on the head of youths of various sizes, based on the likely speed of the ball, and concluded that the force of impact is well below the force that is thought to be necessary to cause a concussion in heading a soccer ball.

But he added that concussions do occur in soccer when the ball hits an unprepared player in the head. He also gave examples of concussions occurring when players accidentally knock their heads into other players while attempting to head the ball, particularly if they are attempting to flick the ball backwards. He noted that soccer professionals do not usually attempt such backwards headings unless they are running to the ball such that there is enough space between themselves and the players behind them. But youths often don't have enough space when they attempt to flick the ball backwards with their heads and they run the risk of knocking their head into the player directly behind them.

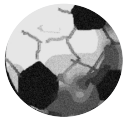
As neuropsychologist Dr. Jeffery Barth pointed out, "We sometimes speak in very broad strokes about the problems of soccer heading and that it may be causing significant neurologic problems, but it may not be the heading that is doing this. It may be the fact that two players go up for the same ball and hit their heads together, which clearly would cause significantly more impairment."

Several speakers noted that players who frequently head the ball tend to be aggressive players and their aggressiveness may make them more susceptible to head collisions with other players. Other frequent causes of concussions in soccer players are head collisions with other players or goalposts or falls where their heads hit the ground, according to Dr. Kirkendall.

Compared to other contact sports, head injuries are common in soccer. In neuropsychologist Dr. Jill Brooks' study of high school soccer players, she found that more than one quarter of them had experienced one or more concussions. Neuropsychologist Dr. Ruben Echemendia reported that in his study of college athletes, over 40 percent of the soccer players had at least one concussion prior to attending college. By comparison, only 30 percent of the incoming football players in the same study reported having had a concussion.

Dr. Brooks found that many high school soccer players neglected to report experiencing a concussion, because they didn't think it was serious or wanted to continue playing in a game. "Most concussions go unreported," she said.

Dr. Kirkendall . . . calculated the impact of a soccer ball on the head of youths of various sizes, based on the likely speed of the ball, and concluded that the force of impact is well below the force that is thought to be necessary to cause a concussion in heading a soccer ball.



PROBLEMS IN DETECTING CONCUSSIONS

Part of the underreporting of concussions stems from the fact that the injury cannot be seen. With a concussion, there is no obvious injury such as when an arm or leg is dislocated. Athletic trainer and sports medicine expert Dr. Kevin Guskiewicz emphasized that "Concussion is a difficult injury to diagnose."

X-rays and other imaging of the brain often cannot detect signs of a concussion. Concussions sometimes can cause small amounts of bleeding usually in multiple areas of the brain, according to neurologist Dr. James Kelly. He said physicians might be able to detect this blood staining of the brain using magnetic resonance imaging (MRI).

But as neuroimaging expert Dr. Shawn Gale pointed out, most doctors do not order an MRI for a concussion patient unless they suspect they have a life-threatening condition, such as major bleeding in the brain or brain swelling. This is because MRIs are more expensive and difficult to do than computerized axial tomography (CAT) scans, he said. But CAT scans usually cannot detect signs of a concussion in the brain.

To diagnose a concussion, consequently, physicians generally rely on the symptoms that the concussed individual reports or other abnormal signs such as disorientation or memory problems. But many of the symptoms of concussions also occur in people without the condition, and, as several speakers pointed out, some of the most widely known symptoms, such as amnesia or loss of consciousness, are frequently lacking in concussed individuals.

SIGNS OF CONCUSSION

- **Vacant stare** (dazed, befuddled facial expression)
- **Delayed responses** (slow to answer questions or follow instructions)
- **Inattention** (easily distracted or unable to follow conversations)
- **Disorientation** (walking in the wrong direction, unaware of time, date, place)
- **Slurred or incoherent speech** (making disjointed or incomprehensible statements)
- **Incoordination** (stumbling, inability to walk tandem or a straight line)
- **Inappropriate emotionality** (appearing distraught, crying for no apparent reason)
- **Memory problems** (exhibited by athlete repeatedly asking a question that has already been answered or showing memory deficits on formal tests of mental status)
- **Loss of consciousness** (paralytic coma, unresponsiveness to stimuli)

Kelly JP and Rosenberg JH. 1997 Diagnosis and management of concussion in sports. Neurology.

Definition and Symptoms of Concussion

Dr. Kelly defined a concussion as a traumatically induced alteration in mental status and suggested that it lies on a spectrum of brain injury somewhere between "being dazed" at the lower end to coma at the other extreme. "The real kicker is that you have to observe and test mental status," Dr. Kelly said.

Unfortunately, as Dr. Kirkendall pointed out, such observation and testing usually isn't done during the heat of a soccer game. He showed a

video of a soccer player experiencing a head collision during a soccer game. Although she was lying on the ground afterwards, the referee did not stop the game.

Contrary to popular belief, concussion does not necessarily involve loss of consciousness, which is just one of many symptoms of concussion. Loss of consciousness frequently lasts only seconds to minutes, so it is often not even detected because of the delay in stopping a game and assessing the condition of a player following a head collision, said Dr. Hergenroeder. "A player will be down on the soccer field and the ref won't stop play. A minute later you go out, and the player's eyes are open, they are responding, so everything looks mild, but you don't know if they lost consciousness," he said. This is a problem since most grading systems use loss of consciousness to indicate a more severe concussion.

Another symptom of concussion is loss of memory (amnesia) and the presence of this symptom usually boosts a concussion from a low grade to an intermediate grade in most grading scales used, said Dr. Guiskiewicz. But in a large study he conducted of concussions in high school and collegiate football players, he found that only about one quarter of all their concussions were accompanied by the symptom of amnesia and only nine percent involved any loss of consciousness. "While I think these are two very important components or parameters to look at when we are evaluating concussion," he said, "we can't forget about all these other things that show up. We're missing the boat if we just focus on these two parameters."

Another symptom of concussion is headache. But this symptom can be problematic when diagnosing concussions because soccer and football players frequently report having headaches without experiencing head collisions, especially female athletes, pointed out Dr. Brooks. "The important thing to realize is that posttraumatic headache is difficult to differentiate from any of the other types of chronically recurring headaches players experience," she said. For example, stress, dehydration, or fatigue can all cause headaches.

Dr. Kelly reported that other early signs and symptoms of concussion are a vacant stare and a slowness to answer questions or follow instructions, disorientation and muddled thinking, slurred or incoherent speech, stumbling and inability to walk in a straight line, balance problems, dizziness, and nausea and vomiting.

Some symptoms do not appear until days to weeks following a concussion, Dr. Kelly added. These symptoms include persistent headache, lightheadedness, diminished attention and concentration, poor memory, easy fatigability, irritability and anxiety and depressed mood, intolerance of bright lights or loud noises and difficulty focusing vision, and sleep disturbance.

There are also more newly discovered subtle signs of a concussion that occur later and appear to be more persistent than the traditional symptoms. Two neuropsychologists, Drs. Barth and Echemendia, reported evidence at the workshop that brain functions are impaired even after the obvious symptoms of concussion disappear.

In two separate studies, they gave college freshmen athletes a battery of tests that measured a number of abilities including attention and concentration, memory, reaction time, problem solving, and verbal learning. They then conducted the same tests in those athletes that suffered concussions during the studies, at various time intervals following the concussions.

Both studies showed that these athletes tended to do the poorest on these tests at 24 or 48 hours following the concussion. Conducting

GRADES OF CONCUSSION

Grade 1	Transient confusion No loss of consciousness Symptoms or signs last less than 15 minutes
Grade 2	Transient confusion No loss of consciousness Symptoms or signs last more than 15 minutes
Grade 3	Any loss of consciousness

Although other guidelines have been established, these are the most widely used by concussion researchers. Note that these are guidelines, established by expert consensus. The studies necessary to establish the link between these or any other concussion grading schemes and the underlying mechanisms of brain injury have not been conducted.

Practice Parameter, Quality Standards Subcommittee, American Academy of Neurology 1997

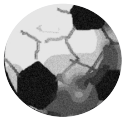
Contrary to popular belief, concussion does not necessarily involve loss of consciousness, which is just one of many symptoms of concussion.

"We are learning that we have underestimated how long it takes to recover from a concussion," noted Dr. Kelly.

a similar battery of tests as well as assessing balance problems on college athletes who experience concussions, Dr. Guskiewicz also found poorest performance on the day following the concussion.

In Dr. Echemendia's study, the athletes' brain functioning assessed by these tests usually was the worst at 48 hours after the concussion. Interestingly, few of the athletes reported any concussion symptoms at this time. "This suggests that these tests can give us some additional information over and above the symptoms and tells us that the symptoms in and of themselves may not be enough," said Dr. Echemendia.

Most of the athletes' scores did not return to the levels they were at the beginning of the study until 10 to 30 days after the concussion. "We are learning that we have underestimated how long it takes to recover from a concussion," noted Dr. Kelly.



CONCUSSION IS A BRAIN INJURY

The spectrum of concussion signs and symptoms and their seriousness can best be understood by exploring what exactly causes them. When the brain is violently moved, as it is in a concussion, it is often twisted which can damage both the brain cells and blood vessels that feed them, explained Dr. Kelly. Neurobiologist Dr. David Hovda added that the mechanical injury further disrupts the chemicals responsible for brain functions which in turn can produce an altered state of consciousness and can explain many of the symptoms associated with what athletes sometimes report as a "ding."

The initial insult to the brain unleashes a biochemical cascade of effects that may not surface for days to weeks following a concussion and makes the brain particularly vulnerable to additional injury, animal and human studies reveal, said Drs. Kelly and Hovda.

Dr. Hovda's studies on rodents revealed that a concussion causes their brains to be flooded with an excess of potassium and calcium ions, potent chemicals that can cause severe damage to cells when they appear in excess. The brain needs large amounts of the sugar, glucose, which is its primary energy source, to activate cellular pumps to counter this flooding of ions, Dr. Hovda said. Normally blood flow to the brain would supply it with this needed sugar, but the flood of calcium ions in the brain restricts blood flow by constricting blood vessels and also hampers the breakdown of glucose, a necessary step for the brain to convert glucose to useable energy. In addition, the blood vessels are constricted by mechanical pressure as the brain swells. Dr. Hovda described the end result as an energy crisis in the brain that can last for weeks following a concussion.

If another concussion occurs before the brain recovers from its first concussion, these energy starved brain cells are then more susceptible to dying. Hovda noted that this biochemically induced vulnerability of the brain is seen following both mild and severe brain injuries in people and is correlated with hampered brain functioning. "I don't know what is so mild about mild traumatic brain injury," he mused, referring to the more formal term for a concussion.

If people are unfortunate enough to experience a second concussion before they have fully recovered from their first, they can experience a life-threatening swelling of the brain, no matter how minor the first or second bang to the head appeared to be, according to Dr. Kelly. This "second impact syndrome" (SIS) can cause major long-lasting brain damage and disability or even death. Avoiding this syndrome should be paramount in deciding when an athlete can safely play sports again, noted Dr. Kelly. (See *Return to Play After a Concussion* section below.)

Death ensues in half of all people with SIS, pointed out pediatrician and sports medicine expert Dr. Hergenroeder, and those that survive the condition are often left with significant brain damage, including impaired hearing or vision, extreme emotionality, and inability to concentrate or pay attention, which leads to poor school performance. SIS is rare, and reports in the literature suggest that it seems to mainly afflict male adolescents and young adults, noted Drs. Kelly and Hergenroeder.

If another concussion occurs before the brain recovers from its first concussion, these energy starved brain cells are then more susceptible to dying.

A number of experts at the conference speculated as to why the young brain seems to be particularly susceptible to SIS. Dr. Hovda pointed out that the human brain does not reach maturity until well after 20 years of age. The young brain has a higher concentration of water, he explained, which makes it more difficult to compress when catastrophic brain swelling occurs in SIS. The continual expansion of the brain within the small confines of the skull results in the death of brain tissue.

Dr. Hergenroeder noted that a child's brain may also be more susceptible to SIS because it fits more tightly inside the skull than an adult's brain. The tighter fit of a child's brain means there is less reserve to accommodate the increased volume when an injury causes the brain to swell.

There are also findings to suggest that the brain of youngsters may be more susceptible to long-lasting brain damage following just one concussion. This damage might hamper their ability to learn.

Dr. Hovda found that when he raised rat pups in a stimulating environment, the portion of their brains responsible for higher thinking functions expanded. These rats become smarter, as seen by the smaller amount of time they need to complete a maze, compared to those raised in a relatively boring environment, Dr. Hovda said. But if these young rats experience a mild concussion, they lose the ability to learn from an enriched environment and to become smarter. Their brains resemble those of otherwise similar mice raised in the normal banal environment, and they take as long as them to complete a maze. "The take-home message from this study is that, at least in animals, traumatic head injury early in life does not create a lot of deficits if it is done by a very mild injury," said Hovda. "But it does seem to come with a cost—a developmental reduction in [the brain's ability to] take in information from the outside world."

Dr. Echemendia found that recently concussed adolescent athletes also tended to do poorly on tests that measured their ability to learn new information.

Akin to what Dr. Hovda found in his rats, Dr. Echemendia found that recently concussed adolescent athletes also tended to do poorly on tests that measured their ability to learn new information. These deficits disappeared over a short period of time. Jon Almquist, one of the participants at the conference, pointed out that concussed youngsters sometimes have difficulty learning during the ten days or so that it takes them to recover from their concussions, so even short-term deficits may affect school performance.

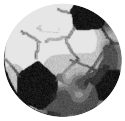
Dr. Brooks added that it was important to keep in mind that any brain impairment stemming from concussions or heading in children or adolescents will affect their academic performance as well as their athletic performance. "We are not dealing necessarily with professional athletes, where this is their livelihood," she said. "The majority of high school and collegiate athletes will not go on to play at an elite level, and they are students as well as athletes."

Intriguing animal research findings presented at the conference by neuropharmacologist Dr. Robin Roof might explain why SIS appears to mainly afflict males. She found that the hormones, estrogen and progesterone, seem to protect rodents from brain damage after they experienced head injury. These hormones are present in higher amounts in adolescent girls and women compared to adolescent boys and men. If they play the same protective role in humans as they do in rodents, Dr. Hergenroeder noted, that could explain why teenage girls and women do not appear as susceptible to SIS.

Dr. Roof noted, however, that there have been conflicting findings as to whether girls and women suffer less brain damage following a blow to the head than their male counterparts. Studies suggest women have a lower threshold for reporting injury and symptoms, and for experiencing certain symptoms such as headache, Dr. Brooks reported. These factors may mask the hormonal effects on brain injury in people to some degree.

"I think what we can say is that these hormones definitely have some sort of neuro-protective effect," said Dr. Roof. "Whether they play the same role in humans and animals hasn't been shown scientifically, but I think that they do."

These findings do not suggest that "our girls are protected enough to not worry about head injury because of these mechanisms," cautioned Dr. Roof. But she added that estrogen and progesterone or information on how they protect against brain damage might lead to effective treatments for head injury.



STUDIES OF SOCCER AND FOOTBALL PLAYERS

The laboratory research previously discussed suggests that the concussions experienced by soccer or football players might be detrimental to the brain. To see if that suggestion holds true on the soccer or football field, a number of experts presented their findings on these athletes.

These experts found hampered brain functioning for a short period following a concussion, and long-lasting brain damage often ensuing in athletes that suffer a second concussion before fully recovering from a first. But many studies presented found no evidence that soccer playing appeared to impair brain functions in the long-term, even when players experienced concussions or did frequent heading during games or practice.

Dr. Echemendia used a broad battery of neuropsychology tests to study brain function in college athletes, but found no significant differences in the mental performance of freshmen soccer players versus freshmen swimmers or other athletes in noncontact sports not likely to foster head injuries. Epidemiologist Dr. Linda Cowan added that since most of these soccer athletes had been playing soccer at least a decade before Dr. Echemendia tested them, if there were long-term neuropsychological consequences from playing soccer, they most likely would have been detected in his study.

Dr. Guskiewicz conducted a similar study on college freshmen athletes and found no significant differences between soccer players and nonsoccer athletes or nonathletic students in terms of Scholastic Aptitude Test (SAT) scores or neuropsychological test results. The soccer players had played soccer for an average of 15 seasons and were more likely to have experienced one or more concussions compared to the other groups. But at the same time, the number of previous concussions among the soccer players was not significantly related to either their SAT or neuropsychological test scores.

Dr. Kirkendall also described a study done by California researchers that found no differences in neuropsychological function between soccer players and track athletes.

To test whether heading causes deficits in mental functions, Dr. Echemendia conducted a battery of neuropsychology tests on college soccer players when they exercised for twenty minutes, versus when they spent an equal amount of time heading the ball. He found no differences in test results between the two, although the players that headed the ball more had more headaches.

Dr. Echemendia also assessed whether college soccer players who frequently head the ball do worse on neuropsychology tests versus those who rarely head the ball. He found no differences between the two groups after they played nearly ten games. (To avoid confusing the effects of concussions on the results he only compared players who hadn't experienced any concussions during the study.)

In contrast to these findings, neuropsychologist Dr. Muriel Lezak presented findings of three other studies conducted on Dutch athletes that suggest the heading and concussions experienced by soccer players can cause long-term brain function deficits.

The Dutch studies found that, compared to swimmers or track athletes, soccer players scored

While several studies of European soccer players raise concerns about the possibility, most studies of American soccer players allay those concerns.

significantly lower on tests that measured visual and verbal memory, visual analysis and planning, and mental flexibility. Those test results suggest that these players would be slower at learning and remembering new material that they hear or see, Dr. Lezak said. The study results were similar for comparisons of amateur as well as professional athletes.

The studies of professional soccer players in the Netherlands also found that soccer players who did more heading or experienced more concussions scored lower on visual and verbal memory tests, visual analysis planning and tasks requiring focused attention and visual scanning. But there were differences between the two groups. Players who were frequent headers displayed decrements in both verbal and visual learning and visuographic tracking speed when compared with those who had been concussed more, although the latter group had decrements in visuospatial organization and fine visual discrimination, she said. The differences between these groups reflect the areas of the brain likely to be affected by concussions versus heading, she suggested.

WHAT IS NEUROPSYCHOLOGY?

Neuropsychology is the study of human behavior as it relates to normal and abnormal functioning of the brain. Clinical neuropsychologists apply scientific knowledge about the relationship between brain function and mental performance to help answer diagnostic questions about medical patients.

Neuropsychological assessment uses behavioral methods such as interviews, observations, paper-pencil and computerized tests, or other specialized procedures to evaluate changes in mental abilities and personality as a result of neurologic disorder. A key component of neuropsychological assessment is the administration of tests of mental abilities such as memory and reasoning. An evaluation may also involve assessment of change in personality, behavioral, and emotional functioning that might reflect neurologic dysfunction or psychological reaction to disease.

People may be referred for neuropsychological assessment after a concussion or other head injury to assess whether certain types of brain functions have been affected. Neuropsychological testing provides a wealth of practical information useful to both the physician and the patient. Test results can help clarify the nature of cognitive difficulties and support the formulation of plans for treatment, rehabilitation, and psychological adjustment.

But some of the experts at the workshop questioned the validity of these findings of adverse effects of heading, and soccer playing in general. Dr. Kirkendall pointed out that the results from studies of European soccer players may not be comparable to those of players in this country, because the Europeans generally use balls that are more highly inflated and thus have more impact when they strike the head. "The alarming numbers we saw from some of the European studies may not translate to the population here," agreed Dr. Guskiewicz. Dr. Kirkendall added that findings in professional soccer players, who are high-caliber, aggressive athletes may not be applicable to middle or high school soccer players.

To date there has been no published study that has provided direct evidence that the practice of heading a soccer ball causes long-term deficits in mental functions. While several studies of European soccer players raise concerns about the possibility, most studies of American soccer players allay those concerns. However, few of those studies were designed to directly study the effects of heading the ball, because they were cross-sectional studies, based on players' condition at only one point in time with no information about their condition before they became elite soccer players. Dr. Kirkendall described one prospective study in which the consequences of heading could be directly assessed by comparing players before and after heading the ball. That study, by Dr. Margot Putukian, showed no differences on neuropsychological tests before and after heading, although that was a short-term study not designed to detect long-term effects. In 2002, Dr. Kirkendall and his colleagues will launch a 5-year longitudinal study of soccer players on the United States National Youth teams. That study should be able to settle the question as to whether heading the ball is followed by brain injury, at least among players at this level. (At ages 16-21, these are already elite soccer players competing at a much higher level than children who play on recreational teams.)

Summing up the human findings presented, Dr. Echemendia said, "The data show that, all

in all, playing soccer is not dangerous to your brain, at least based on what we know at this point in time. The data also show that heading, in and of itself, does not seem to be a significant problem, at least in those people that it has been studied. However, heading does put the player at risk in the sense of having their head make contact with a number of different objects—somebody else's foot or head, or a goal post—so we need to put that caveat in there."

Thus far no published study has provided direct evidence that the practice of heading a soccer ball causes long-term deficits in mental functions. Nor has any study been published that proves heading has no long-term effects. To date, the best evidence is suggestive. The long-term effects of repetitive heading will not be known until the completion of well-designed, long-term studies that evaluate players before and for years after they frequently head soccer balls. The tables on the following page summarize studies presented at the workshop, and are not a comprehensive summary of all studies relevant to head injury in soccer.

Helmets Are Not Designed to Prevent Concussion

The notion that soccer might put youths at risk for brain injury has circulated in the popular media and that has led some to suggest that soccer players wear protective headgear. But as bioengineer Dr. Joseph "Trey" Crisco pointed out, there are a number of concerns with this suggestion. For one, no protective headgear currently on the market is designed to protect against concussion. Today's helmets are designed to meet standards for reducing the risk of serious and fatal brain injury and these standards are limited to reducing injury caused by a linear acceleration, or a 'straight on' blow to the head. But a blow that causes concussion typically includes rotational acceleration, in which the brain gets twisted. Current helmets and standards are not designed to take this type of blow into account.

Dr. Crisco, who is the Director of Research for the National Operating Committee on Standards for Athletic Equipment, noted that football and other protective helmets were developed based on data from experiments in which high impacts were applied to the heads of cadavers from elderly men. He questioned the relevancy of that data set to the youths and females that play soccer and suggested that helmets developed from this data may not be as protective against brain injury in youths and women as they are in men.

"The concern that I have from an engineering perspective is that if you place headgear on children [who play soccer] there is going to be a limited understanding," he said. "We talk to trainers, to equipment managers, and they are very surprised when I say that no helmet is designed to prevent concussions." Most parents, players, and coaches are going to assume it will prevent concussions when it is not designed to do so, he noted. "And then we have the Superman phenomenon," he added. "You place equipment on players and they believe they are less at risk so they may place themselves more at risk in getting involved in heading or head-to-head player contact than they normally would."

Dr. Crisco suggested that it might be more cost effective to develop standards for soccer balls so that they are not likely to cause brain injury, than to do so for protective soccer headgear. The structure, weight, and other material properties of soccer balls all influence the amount of impact they can have on the head, he noted. The research needed to develop standards for soccer balls would be easier and less expensive to conduct than the research needed for soccer headgear, according to Dr. Crisco.

We talk to trainers, to equipment managers, and they are very surprised when I say that no helmet is designed to prevent concussions."
[Trey Crisco]

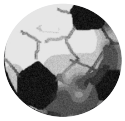
BOX 1A. STUDIES THAT SUGGEST HEADING CAUSES BRAIN INJURY

Study Subjects	Results	Investigators
33 Dutch amateur soccer players compared to 27 elite athletes in noncontact sports (swimming and track)*	Compared to the control groups of athletes, soccer players showed deficits in cognitive functions. Those deficits were correlated with the number of concussions.	Eric Matser, Muriel Lezak and others, 1999. *JAMA*
53 Dutch professional soccer players compared to 27 elite athletes in noncontact sports (swimming and track)	Compared to the control groups of athletes, soccer players showed deficits in certain cognitive functions.	Eric Matser, Muriel Lezak and others. 1998. *Neurology*
84 premier league professional soccer players	The number of concussions that players remembered having in their lifetime was associated with cognitive deficits. Players who headed the ball more often also showed cognitive deficits, although the specific deficits were different for the frequently concussed players than deficits seen in the frequent headers.	Eric Matser, Muriel Lezak and others. 2001. *Journal of Clinical and Experimental Neuropsychology*

*Although they are officially amateur players, they are nonetheless elite athletes who play in highly competitive leagues. The average age of the athletes in this study was 25 years, and they had played soccer an average of 17 years, practiced 4 hours per week, and played 36 games per year.

BOX 1B. STUDIES THAT SUGGEST HEADING DOES NOT CAUSE BRAIN INJURY

Study Subjects	Results	Investigators
91 U.S. varsity collegiate soccer players vs. 96 varsity collegiate athletes in noncontact sports and 53 student controls.	No significant differences between the groups for SAT score or neuropsychological tests.	Kevin Guskiewicz, Stephen Marshal, and others. 2002. *American Journal of Sports Medicine*
100 U.S. varsity collegiate soccer players tested just before and after repeatedly heading a soccer ball.	No decrease in neuropsychological test scores were seen after 20-minute heading practice sessions.	Margot Putukian, Ruben Echemendia, and others, 2001. *Clinical Journal of Sports Medicine*
20 members of the U.S. Men's National Soccer Team training camp compared to 20 elite male track athletes of the same age.	Head injury symptoms were associated with head injuries received while playing soccer, but not to the numbers of years playing soccer or how many times a player headed the ball.	Sheldon Jordan. 1996. *American Journal of Sports Medicine*
133 U.S. varsity collegiate soccer players and 111 athletes in noncontact sports (Both groups included men and women.)	No significant difference in mental performance.	Ruben Echemendia, Margot Putukian, and Jared Bruce (*unpublished data*)
58 U.S. varsity collegiate soccer players with different exposures to heading soccer balls.	No difference was seen in neuropsychological test results for players who frequently headed soccer balls compared to those who rarely did.	Ruben Echemendia Margot Putukian, and Jared Bruce (*presented at American Medical Society of Sports Medicine and American Osteopathic Academy of Sports Medicine Annual Meeting, April 2001*)



POLICY IMPLICATIONS

The information presented at the conference raised a number of important policy implications, including the neuropsychological assessments and other factors that should be considered for determining how soon after experiencing a concussion a player can return to the playing field, the importance of educating the spectrum of people involved in soccer on the consequences of concussion, the signs and symptoms of concussions, about the guidelines for when to allow players to return to play after a concussion, the need for more athletic trainers in school athletic programs, and when to teach heading to children.

Return to Play After a Concussion

The main goal of return-to-play guidelines is to avoid the serious, and possibly fatal, complications of a second concussion occurring too close on the heels of the first. Dr. Guiskiewicz presented evidence that players who experience one concussion are three or four times more likely to experience additional ones than their teammates who have never had a concussion. This probably relates to their style of playing, according to Dr. Hergenroeder, and points to the need to prevent these players from permanently damaging their brains.

There are a number of return-to-play guidelines used to determine how soon athletes can safely play their sport after they've had a concussion. Most of these guidelines recommend safe time-out periods based on the seriousness of the concussion, as determined by the loss of consciousness or amnesia.

For example, concussed players who never lost consciousness or experienced amnesia are allowed to return to the game after fifteen minutes if they have no other symptoms of the concussion at that time. If players experience amnesia following their concussion, however, they are usually not allowed to play again until one week after the concussion, and then, only if they are symptom-free for the entire week.

If players lose consciousness following the concussion, that time-out period is extended to at least two weeks, assuming they have not shown any symptoms during that period. If a player has already had two or more concussions during the same season, the time period away from playing should increase for each concussion.

Several of the speakers pointed out shortcomings to these commonly used return-to-play guidelines, and additional factors that need to be considered. "There are increasingly sensitive measures that we need to use in our batteries of evaluating athletes, in order to be more certain that they are actually safe to go back," noted Dr. Kelly.

One shortcoming to these guidelines, pointed out by Dr. Echemendia, is that they rely on the loss of consciousness to predict the severity of the concussion. But unless that loss of consciousness occurs for a long period of time—thirty minutes or more—data suggest it doesn't predict the severity of a concussion in the mild range, Dr. Echemendia said. In addition, as mentioned previously, players are often not evaluated soon enough after a concussion to determine if brief losses of consciousness occurred.

Dr. Echemendia did think, however, that the length of time players experienced amnesia after a concussion was a telling factor in how severe the concussion was, and thus how quickly the player can return to the field. "Do we have a posttraumatic amnesia that exists for a minute or do we have one that is 12 hours long? It is important to take a look at that," he said.

Another major problem with most current return-to-play criteria is that they rely heavily on athletes' reporting of symptoms to assess whether they should return to play, according to Dr. Echemendia. But as Dr. Kirkendall pointed out, players will "lie, lie, lie to get back in a game." Dr. Echemendia concurred and recommended that "When a player is standing in front of you and they look dazed or goofy, and they are telling you that they are absolutely fine, don't take their word for it."

Dr. Echemendia gave another reason for not relying on players reporting their symptoms, which is that they may not even be aware of them. He also noted that some concussion symptoms, such as headache, are so common that they are difficult to distinguish from other conditions. He pointed out that nearly one-third of the athletes he studied reported concussion symptoms at the beginning of the study, before experiencing any head injuries on the college playing field. "If we base our return-to-play decisions solely on their reports of symptoms, then we end up in trouble," he said.

Dr. Guskiewicz called for more objective, quantitative measures of impaired brain functioning that would disqualify a concussed, brain-injured athlete from returning to the playing field. Those measures would include neuropsychological assessments as well as objective measures of posture and balance. As an example of the need for better assessment, he brought up the problem of balance, which is often disturbed in people after a concussion. And yet, most assessments of balance are inadequate and inconsistent. "One person may think that the individual has a gross sway, and another person may think they have a very mild or moderate sway," he said.

Dr. Guskiewicz developed a balance error scoring system that enables the accurate assessment of balance. This testing system grades athletes on their ability to maintain a position while standing on one foot and other tasks. The tests require only an inexpensive piece of foam and can be done on the sidelines of a playing field.

Dr. Kelly added that there are devices, such as those that can measure abnormal eye movements, which can also aid the objective determination of certain concussion symptoms.

Several speakers addressed the importance of using neuropsychological assessments in return-to-play decisions. These assessments can objectively determine when a number of brain functions return to normal following a head injury, according to Dr. Echemendia. As he said, "return-to-play decisions are very difficult because we are trying to find that one moment when it is safe to return to play for someone who has a condition we can't see." Neuropsychological assessments can help "see" if that condition has resolved, he said, particularly if baseline, normal values in these assessments are known for the players. Such baseline data could be collected by testing athletes when they first come on board a team, prior to the start of any games. Neuropsychological assessments can also determine if some of a player's symptoms, such as headache, are due to the head injury or some other cause, noted Dr. Echemendia.

But as Dr. Guskiewicz mentioned, neuropsychological functioning is just one piece of a complex concussion puzzle and other factors, such as balance problems and other symptoms also need to be considered when making return-to-play decisions. "There are many pieces to this puzzle, several of which we don't even know, and you can't look at just one piece of it," he said. He also added "no two concussions are created equal." Some athletes with concussions may do poorly on neuropsychological tests, but well on balance tests, and others will do just the opposite. "That's why we need to try to make sure that we are looking at every piece of that puzzle in making these decisions," he said.

Another factor that both Drs. Guskiewicz and Echemendia called attention to was the importance of a player's concussion history in deciding when they could safely return to play. "The number, spacing, and severity of previous concussions all need to be taken into account," said Dr. Echemendia. "One of the greatest issues is not necessarily the number of concussions

you've had," he said, "but how closely spaced they are because it gets to the whole issue of the vulnerability of the brain. If the brain is still vulnerable and you have another concussion, that may lead to a more severe outcome."

Dr. Echemendia also suggested considering player and team factors such as their style of play and position when making return-to-play decisions. If they tend to "play with their heads" or are in a position that puts them in greater likelihood of experiencing another head injury, then a longer delay before returning them to play may be warranted, he said. Another important factor, he added, is the player's willingness to return to play. "It is very telling when you have a player who tells you 'you know doc, I feel scared about going back into the game,'" Dr. Echemendia said. Those players should not usually be returned to the playing field, he said.

Another factor in balancing the risk versus benefit assessment of when players should return to a game, raised by Dr. Echemendia, is the importance of the game and the athletic career aspirations of the player. "Is this an athlete who doesn't want to go any further than high school in their playing, or is it someone who wants to play at a higher level and just signed a 34 million dollar contract?" he said. "You also need to be aware that the importance of the game might try to pressure you to put that player out on the field too early," he added.

Another factor to consider is the field conditions, according to Dr. Echemendia. A wet slippery field poses more hazards than a dry one, he pointed out.

Dr. Hergenroeder stressed the importance of having qualified physicians examine athletes who have experienced a concussion before they are allowed to return to playing in a game. As he pointed out, this often does not happen and instead coaches make the decision on when a player can resume playing. "Even well-intentioned coaches are probably not making the right decisions in the interest of the player," he said.

Dr. Hergenroeder also noted that for many athletes, the sport they play is a major part of their lives and restrictions on their playing can be a hardship for them. To make it easier for these devoted athletes, he suggested that recently concussed players who have no symptoms, but can't yet return to playing a game, can still work out with their teams during practices and participate in noncontact drills.

Education

Dr. Brooks presented findings from her study that indicated most of the people involved in high school sports, from the players to the team doctors, were not aware of the seriousness of concussions and how to diagnose or treat them. "We found that most student athletes at the high school level do not have information about concussion," she said.

Dr. Hergenroeder pointed out that in his experience, the team physicians for many high school and middle school teams tend to be obstetricians, pediatricians, or family practice physicians who have no training in concussion management. "The parents on the sidelines are pleased to know that there is a physician there," he said, "but this physician may not have the skills for handling some of this."

Dr. Brooks concurred and noted that when she surveyed family practice physicians within the state of New Jersey, she found that less than half of them felt confident treating concussions. Only a third of them felt confident making return-to-play decisions. And what is perhaps most disconcerting, only ten percent of them received a passing grade on her concussion questionnaire. "We need to educate physicians," she said.

"Right now family practitioners, internal medicine doctors and pediatricians are the gatekeepers before anybody ever makes it to a specialist like a neurologist or neuropsychologist," Dr. Brooks said. "If we are seeing that our medical providers do not have the most current up-to-date information about what a concussion is or is not, then I think we really have our work cut out for us."

Although 97 percent of the athletic trainers Dr. Brooks surveyed received a passing grade on her concussion test, 17 percent reported using no objective method to assess concussion consistently, and for deciding when athletes could return to playing a game following a concussion. In addition, 60 percent reported that they had never discussed concussion or return-to-play decisions with their team physicians.

"One of the greatest issues is not necessarily the number of concussions you've had," he said, "but how closely spaced they are because it gets to the whole issue of the vulnerability of the brain. If the brain is still vulnerable and you have another concussion, that may lead to a more severe outcome." [Dr. Echemendia]

One participant stressed the importance of educating coaches because it often is the coach that is making return-to-play decisions. Only one-third of the student athletes that Dr. Brooks surveyed reported receiving any information about concussions from their coaches. Another participant pointed out that the majority of youths play in amateur leagues with volunteer parent coaches and that these coaches must be educated about concussion as well.

Education of the parents of youth athletes is important, added Dr. Brooks. By notifying them of the symptoms associated with concussions, "parents will look at their kids seeing stars, or vomiting or having a sensitivity to lights or sounds in a different way," she said.

Dr. Brooks added that officials at youth games should also be educated about the signs and symptoms of concussion, as they are the ones responsible for stopping a game once a player receives a head injury. They are also responsible for ensuring that the rough reckless play likely to cause head injuries does not occur out on the playing field.

Dr. Kirkendall described the case of a high school soccer player who received two concussions in one game from the same player. Using illegal maneuvers, this player forced her to fall on two separate occasions and both times she hit her head. The concussed player went from being an A student to a struggling student and essentially lost an entire semester of school. The player who fouled her twice was not called for a foul either time or restricted from playing. "Reckless play is fairly common," he said, "and cautionary objection to this reckless play is fairly rare."

Mr. Jon Almquist, who participated in the workshop, coordinates high school athletic training programs in Fairfax County, Virginia, and chairs the secondary schools athletic training committee of the National Athletic Trainers Association. He noted that "We have enough information now to roll out the education component, but it needs to go to all levels—not only the youth coach, but the medical community, the coaching community, and the parents and athletes." Education of the athletes on the signs and symptoms of concussion "has potentially saved some lives," he added, "because they're looking out for their friends." Because they have been educated about the symptoms of concussion, they recognize them in their head-injured teammates and have brought them to the attention of the coach or team athletic trainer, he said.

"We have enough information now to roll out the education component, but it needs to go to all levels—not only the youth coach, but the medical community, the coaching community, and the parents and athletes." [Mr. Jon Almquist]

To aid with concussion education, Dr. Brooks suggested partnering with the Brain Injury Association of America, and state athletic associations. She also suggested working with insurance companies so they will give school districts a lower insurance rate for their sports programs if they include an educational program about concussion.

Dr. Brooks also thought it important to meet with school board members and principals before running concussion education programs in the school system. "If it comes down from the top, then potentially the coaches and the athletic trainers will participate in these programs and so will the parents," she said.

She noted that in the concussion education program she ran in a New Jersey school system, none of the parents have ever pulled their children out of athletic programs because they were scared by the information she presented during her education program.

To help with educating the public about the seriousness of concussions, Alan Bergman of the Brain Injury Association of America suggested the formal medical term for concussion, "mild traumatic brain injury," be changed. "As a lobbyist, I can tell you working on Capitol Hill last year on the Traumatic Brain Injury Act, we struggled to get one sentence in that legislation about looking at mild traumatic brain injury," he said. "The response was 'well, if it is a mild injury, it goes away.' So nomenclature is a major issue here and it is a barrier to public and professional education."

Mr. Bergman said that even the term concussion connotes nothing more serious than just a three-day headache or bump on the head to most people, according to a Harris poll his organization ran last year. "Maybe we should just say 'brain injury,'" he suggested.

He added that the problem with the term "head injury" is that most people assume it doesn't affect the brain. "Somehow people

believe the skull is an iron vault that protects that organ inside called the brain," he said. Another participant suggested calling a concussion a "moderate brain injury." This term would preserve the acronym already used for mild brain injury, he noted, yet distinguish a concussion from a more severe brain injury.

Athletic Trainers

Dr. Guskiewicz suggested recommending that all high schools with sports programs have certified athletic trainers. These sports medicine professionals are not only well versed in the signs and symptoms of concussions, he said, but because they deal with the team athletes on a daily basis, they are often better at evaluating head injuries than a physician.

"They know the personality and intelligence level of the athlete so they can detect when there is something out of sync or just not normal," he said. Dr. Guskiewicz thought athletic trainers should be part of the team of neuropsychologists, neurologists, and physicians that are responsible for evaluating players' head injuries.

According to Dr. Guskiewicz, athletic trainers are currently present at 38 percent of all high schools in this country. He noted that there are several states right now that have legislation in the works that require placing certified athletic trainers in every school district. Even then, it is unlikely that many school districts would have funding to support enough trainers to attend every game of every relevant sport for all schools.

Heading

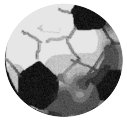
Dr. Brooks noted that heading is a valued part of the soccer game and adds an important dimension to play. Although Dr. Echemendia pointed out that there currently is no evidence that heading, when done properly, causes brain injury in adults and late adolescents, there still was debate on when youths should be taught to do this practice.

Dr. Hergenroeder suggested heading should be taught early, such as before the middle school years, when youth soccer players are usually first taught to head the ball. "If you teach them how to head correctly, that gets them out of trying things that they see the pros doing and they don't know how to do, such as the backward head," he said.

Dr. Brooks added that the American Youth Soccer Organization recommends not teaching heading to players below age 10. "But if you talk to trainers, coaches, and a lot of people that are working in the area of educating players," she said, "many claim it is really important to potentially develop the neck musculature and have athletes prepare to take headers prior to age 12, so that once they become 12 or 13, they are not confronted with situations that they don't potentially know how to deal with."

But one participant at the workshop questioned whether children younger than 12 have the musculature and skeletal development to lock their heads in place, which is an important element of safe heading technique.

Dr. Brooks also noted that some people have suggested limiting heading in youths to certain areas of the playing field as a way of eliminating head trauma from some of the longer, more directly returned balls.



SUMMARY

As Dr. Hergenroeder reminded the audience, the policies that really matter are those that influence what happens on the field. From this perspective, the policymakers most relevant to head injuries in youth soccer players are the national sports associations and local organizations such as schools and soccer clubs.

As to federal policies, safety issues in children's sports are often covered by the Consumer Products Safety Commission (CPSC) insofar as sports equipment is involved. In May 2000, the Commission held a workshop to examine the possible use of helmets in youth soccer players, but did not find that the available evidence warranted the mandatory adoption of helmets. The Centers for Disease Control and Prevention (CDC) also monitors childhood injuries and funds research on injury prevention, but has not recommended against heading in youth soccer. Finally, the National Institutes of Health is the major federal supporter of medical research, but currently supports fewer than half a dozen grants related to head injuries in children's sports.

No peer-reviewed studies have been published to support or refute the use of helmets in soccer and no authoritative medical or sports organizations have recommended the use of helmets in soccer.

Different speakers at the workshop viewed the dangers of heading in a variety of ways. Most, but not all, of the studies presented suggested that heading a soccer ball does not cause cognitive deficits. However, without definitive data there can be no conclusive resolution about the dangers of heading. Further, all of the studies reported at the workshop and in the published literature were based on adults or high school age players; none of the available data are based on pre-adolescent children. Several of the studies were not designed to definitively separate the effects of concussions from repetitive heading, an issue raised by several speakers during the workshop. Clarification of the long-term consequences of heading soccer balls awaits the outcome of well-designed prospective studies, such as the 5-year study being led by Dr. Kirkendall and funded by the United States Soccer Foundation.

In the meantime, the American Youth Soccer Organization recommends that children under 10 should not head the ball but continues to support the practice of purposeful heading for older soccer players. No peer-reviewed studies have been published to support or refute the use of helmets in soccer and no authoritative medical or sports organizations have recommended the use of helmets in soccer.

Ironically, while there has been considerable media coverage about the possible dangers of heading, there has been comparatively little public attention to the dangers of concussion. Without exception, every speaker at the workshop concurred about the need for a greater attention to concussions in youth sports. Concussions and especially multiple concussions are both more frequent and more serious than is commonly understood.

Many of the speakers emphasized that the people on the playing field and the sidelines—the players, referees, coaches, and trainers—especially need to become educated about the signs and symptoms of concussion and need clear evidence-based guidelines about how to decide when a player can return to play after sustaining a concussion.

FOR MORE INFORMATION

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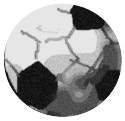
5. Putukian M, Echemendia RJ, and Mackin S, The acute neuropsychological effects of heading in soccer: a pilot study. *Clin J Sport Med.* 2000 Apr;10(2):104-9.



APPENDIX A: WORKSHOP AGENDA

8:30 a.m. **Opening Remarks**

Linda Cowan
University of Oklahoma and
Michael Johnston
Kennedy Krieger Institute, co-chairs

Overview of Head Injury in Sports

James Kelly
Northwestern University

Dangers of Head Injury in Soccer

9:00 a.m. Cognitive Impairment Associated with Soccer

Muriel Lezak
Oregon Health Sciences University

9:20 a.m. Prevalence of Head Injuries in Youth Soccer

Don Kirkendall
University of North Carolina

9:40 a.m. Risk Factors for Head Injury in Youth Soccer Players

Jill Brooks
Univ. Medicine and Dentistry of New Jersey

10:00 a.m. General Discussion

The Brain's Response to Injury

10:20 a.m. Biomechanics and Biology: Animal Studies

David Hovda
UCLA

10:40 a.m. Sex Differences in the Brain's Response to Injury

Robin Roof
Pfizer, Inc.

11:00 a.m. General Discussion

10:45 a.m. BREAK

Detecting Brain Injury

11:20 a.m. Neuropsychological Assessment of Sports-Related Concussion

Jeffrey Barth
University of Virginia

11:40 a.m. Cognitive Testing: Diagnosis and Recovery of MTBI

Ruben Echemendia
Pennsylvania State University

12:00 p.m. Neuroimaging of Brain Injury and Neurospychological Assessment

Shawn Gale
University of Virginia

12:20 p.m. General Discussion

12:30 p.m. LUNCH

On the Field: Preventing and Managing Brain Injury

1:15 p.m. Neuropsychology's Role in Return-to-Play Criteria

Ruben Echemendia
Pennsylvania State University

1:35 p.m. Sports-Related Concussions: Bridging the Gap Between Research and Clinical Practice

Kevin Guskiewicz
University of North Carolina

1:55 p.m. Management of Head Injury in Young Athletes

Albert Hergenroeder
Baylor College of Medicine

2:15 p.m. General Discussion

2:25 p.m. BREAK

Remedies Under Consideration

2:35 p.m Educational Programs and Prevention of Head Injury
Jill Brooks
Univ. Medicine and Dentistry of New Jersey

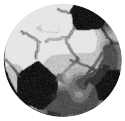
2:50 p.m. Prospective Studies in Progress
Don Kirkendall
University of North Carolina

3:05 p.m. Biomechanics and Prevention of Head Injury in Sports
Joseph "Trey" Crisco
Brown University

3:25 p.m. General Discussion

Roundtable Discussion: Implications for Policy and Practice

4:30 p.m. ADJOURN



APPENDIX B: SPEAKER BIOGRAPHIES

Linda D. Cowan, co-chair, is George Lynn Cross Research Professor in the Department of Biostatistics and Epidemiology at the University of Oklahoma College of Public Health. Her research activities have been primarily in the areas of neurological disorders in infants and children, cardiovascular diseases, and research methodologies. She is currently working with a doctoral candidate on a study of risk factors for injury in middle and high school football players. Dr. Cowan has served on several IOM committees dealing with vaccine-related issues.

Michael V. Johnston, co-chair, is Senior Vice President and Chief Medical Officer at Kennedy Krieger Institute, as well as director of both the Division of Neurology and Developmental Medicine and the Neuroscience Laboratory. Dr. Johnston is an attending physician at both Johns Hopkins Hospital and Kennedy Krieger Children's Hospital. Dr. Johnston and his group perform clinical and basic laboratory research focused on developing therapies to reduce brain injury in infants and children as well as to promote recovery by enhancing brain plasticity. His laboratory was one of the first to describe the mechanisms through which the neurotransmitter glutamate triggers brain injury from lack of oxygen, trauma, and other insults.

Jeffrey T. Barth holds the John Edward Fowler Professorship in Clinical Neuropsychology, an endowed chair in the Eminent Scholar's Program, University of Virginia Medical School. He is Chief of the Division of Medical Psychology and Director of the Neuropsychology Center in the Departments of Psychiatric Medicine and Neurological Surgery. He is recognized nationally and internationally for his research on the neuropsychological sequelae of mild traumatic brain injury and the use of sports-related concussion as a laboratory assessment model for brain trauma.

Jill Brooks is Director of the Neuropsychology Program in the Department of Neurology at the Robert Wood Johnson University Medical Group. The Neuropsychology Program provides diagnostic evaluations to elucidate brain and behavior relationships. Dr. Brooks' research interests are in clinical neuropsychology and concussion in sports.

Joseph "Trey" Crisco is Director of the Bioengineering Laboratory, Associate Professor of Orthopaedics, and Adjunct Associate Professor of Engineering at Brown University, Providence, RI. He is Director of Research for the National Operating Committee on Standards for Athletic Equipment (NOCSAE) and serves on the medical advisory committees for USA Baseball and US Lacrosse. Dr. Crisco's primary research focus is on injury mechanisms ranging from muscle contusions to advanced imagining modalities of in vivo joint mechanics. His work is supported by the Whitaker Foundation and the NIH, with over sixty peer-reviewed manuscripts and ninety abstracts.

Ruben J. Echemendia is Clinical Associate Professor of Psychology and Director of the Psychological Clinic at The Pennsylvania State University. His clinical and research interests include clinical neuropsychology and sports neu-

ropsychology. He is particularly interested in the diagnosis and recovery of function after mild traumatic brain injury. Dr. Echemendia is the Director of Penn State's Cerebral Concussion Program, a multi-sport prospective study of concussion. He is the Co-Director of the National Hockey League Neuropsychological Testing Program and a consultant to the Pittsburgh Penguins Hockey Club.

Shawn D. Gale is Assistant Professor in the Department of Physical Medicine and Rehabilitation at the University of Virginia Health System. His clinical activities include neuropsychological assessment and consultation of various neuropathlogical conditions, consultation with inpatient and outpatient rehabilitation treatment teams, and in designing appropriate treatment plans and monitoring treatment outcome. His research interests include neuroimaging and clinical outcome as it relates to the neuropathological, neurocognitive, and neurobehavioral effects of CNS injury and disease.

Kevin Guskiewicz is Associate Professor and Director of the Sports Medicine Research Laboratory in the Department of Exercise and Sport Science at the University of North Carolina. Over the past eight years, his research has focused on sport-related concussion, investigating the effect of sport-related concussion on postural stability and cognitive function and the long-term effect of soccer participation on neurocognitive performance in college players. Dr. Guskiewicz has been the recipient of eight funded research grants, and has published 20 journal articles and three textbook chapters related to mild head injury in sport. In 1997, he chaired the 1997 NATA Pronouncement Committee on Mild Head Injury in Sport, and served as editor for the Journal of Athletic Training's Special Issue on Concussion in Athletes (October 2001).

Albert C. Hergenroeder is Associate Professor or Pediatrics and Chief of the Section of Adolescent Medicine and Sports Medicine, Department of Pediatrics, Baylor College of Medicine; Chief, Sports Medicine Clinic, Texas Children's Hospital. He is Board Certified in Pediatrics, Adolescent Medicine and Sports Medicine. He is a team physician for one college and three high school athletic programs. His expertise is in clinical management of sports injuries.

David A. Hovda is Professor of Neurosurgery and the Director of the UCLA Brain Injury Research Center. Over the years his research has focused on the pathobiology of traumatic brain injury and, specifically, on the factors that contribute to cellular vulnerability and consequences when mild traumatic brain injury occurs early in life. He is councilor and past-president of the National Neurotrauma Society and has served as consultant for the National Football Leagues, several biotechnology and pharmaceutical firms, and on advisory panels for the National Institute of Neurological Disorders and Stroke.

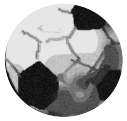
James P. Kelly is Associate Professor of Clinical Neurology at Northwestern University and Medical Director of the Chicago Neurological Institute. He received the 1997 James Brady Award from the Brain Injury Association of Illinois. Dr. Kelly helped develop severity and return-to-play criteria for the American Academy of Neurology.

Donald T. Kirkendall is Clinical Assistant Professor in the Department of Orthopedics at the University of North Carolina School of Medicine and Adjunct Professor in the Department of Physical Education, Exercise & Sports Sciences. He is a Fellow of the American College of Sports Medicine and serves on the Editorial Board for the Soccer Journal of the National Soccer Coaches Association of America. His research interest is in the physiology of exercise.

Muriel D. Lezak is Professor of Neurology, Psychiatry, and Neurosurgery at Oregon Health Science University. Dr. Lezak has a long-standing interest in assessment of mild traumatic brain injuries (TBI), particularly as they relate to practical, everyday functioning and to rehabilitation procedures and prospects. Her interest in the neuropsychological ramifications of soccer was sparked by the opportunity to work with the Dutch neuropsychologist Eric Matser on the

analysis and interpretation of data from a research series involving Dutch soccer players, both professional and amateur. Her publications include articles on TBI assessment, assessment for rehabilitation, and the psychosocial problems associated with TBI; she has edited a book on TBI and may be best known for her book, *Neuropsychological Assessment*.

Robin L. Roof is a Research Associate in CNS Pharmacology at Pfizer. She has 12 years experience conducting research, as well as 30 publications in the area of gender differences in brain injury. Dr. Roof conducted the original research that demonstrated the neuroprotective effects of the sex-related hormone progesterone in the early 1990s. She has since published a number of papers describing neuroprotective roles of progesterone and estrogen as well as gender differences after brain injury.



APPENDIX C: WORKSHOP REGISTRANTS

Allan Bergman
Brain Injury Association of America

Joseph Bleiberg
National Rehabilitation Hospital

Barry Boden
Uniformed Services University of Health Sciences and
National Institutes of Health

Christine Bolger
National Association for Sport and Physical Education

Fred Bowen
Washington Post / KidsPost

Ruth Brenner
National Institute of Child Health and Human Development

Milton (Mac) Brown
Arlington Soccer Association

Stephanie Bryn
Health Resources and Services Administration

Matthew Buccilli
National Safe Kids Campaign

Julie Gilchrist
Centers for Disease Control

Jason Goldsmith
U.S. Consumer Product Safety Commission

David Kim
Johns Hopkins University

Andrew Lincoln
Johns Hopkins University

Mary Lord
U.S. News and World Report

Jonathan Midgett
U.S. Consumer Product Safety Commission

Richard Monastersky
Chronicle of Higher Education

Suad Nakamura
U.S. Consumer Product Safety Commission

Vito Perriello
National Federation of High School State Associations

John Reynolds
Fairfax County Public Schools

Gordon Smith
Johns Hopkins University Injury Prevention Center

Diane Snustad
University of Virginia

Christine Spain
President's Council on Physical Fitness and Sports

Thomas Terrell
University of South Carolina

Sean Turbeville
University of Oklahoma HSC

Charles Webb
Uniformed Services University of Health Sciences

Susan Winn
Consumer Federation of America Foundation

Randy Wykoff
Office of Disease Prevention and Health Promotion
Health and Human Services