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Fighting Heatstroke in Football

E. Randy Eichner, MD, FACSM

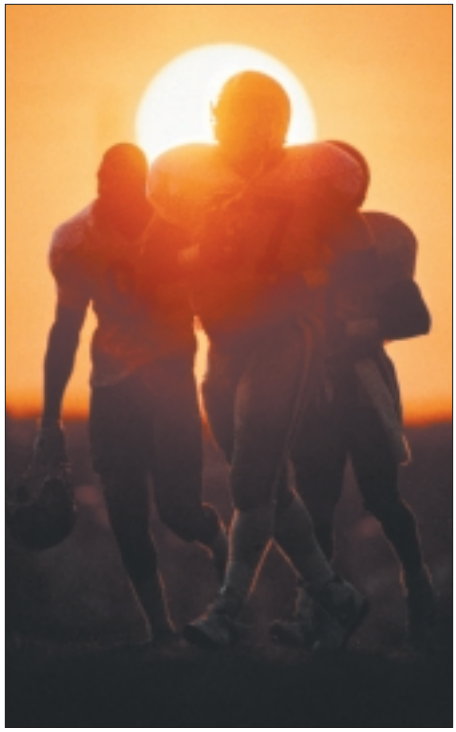
For many football teams, summer brings grueling workouts in brutal conditions — searing heat and stifling humidity. For players giving their all in the dog days, mild heat illness is common and grave heatstroke always a threat. Since 1995, an average of three players each year have died of heatstroke. This tragic statistic held true in the summer of 2001, when three football players — one high-school, one college, one pro — died of heatstroke. Heat illness can develop rapidly in football and warning signs can be subtle. Yet early diagnosis and proper treatment can save lives. The risk of heatstroke can be dramatically reduced by understanding the risk factors and taking precautions. This article covers key risk factors for heatstroke in football and offers tips on prevention and treatment.

Confluence of Risk Factors

Just as the Mississippi is a confluence of streams, heatstroke is a confluence of risk factors. For example, the three players who died last year were highly motivated, exercising hard in the July sun, likely unfit or overweight or unacclimated and surely dehydrated. Key risk factors for heatstroke in football are covered below.

The 1-2 Punch: Most heatstroke deaths occur on Day 1 or 2 of two-a-days. As in soldiers in basic training, a prime time for heatstroke is the day after an exhausting and dehydrating day in the heat.

What Heat, Coach? Even modest climes can kill. Body temperature tends to rise — in a sawtooth line — ever-higher the longer the practice goes on. Especially so in full football gear, some heatstroke deaths have occurred when ambient temperature was only 80-85°F and relative humidity less than 60 percent.



Summer brings grueling workouts in brutal conditions. Staying properly hydrated is the best way to prevent dehydration and heat illness.

Unacclimated: Lack of acclimation is a cardinal predictor of heat illness in football two-a-days. Getting used to the heat takes time. Heat acclimation, much of which can be achieved in a week or two, leads to better drinking and the body holds onto water and salt, increasing blood volume so the heart pumps more blood to the muscles at a lower heart rate. Heat-fit athletes also sweat sooner, heavier and over a wider body area, so they stay cooler. The cooler they stay, the better they play.

Dehydration Drains: Players in two-a-days can easily sweat 1-2 quarts an hour, and most drink less than they sweat. The result is dehydration. Dehydrating as little as 2% body weight — only 5 pounds in a 250-pound linebacker — can impair physical performance. Advancing dehydration increases heart rate and decreases cardiac output. Perceived exertion of the work increases as dehydration drains mental sharpness and willpower along with muscle power and endurance. Dehydrated players also heat up faster.

Fitness Protects: Physical fitness, especially aerobic fitness, confers some of the same physiologic benefits as heat acclimation. Fitness also makes workouts less taxing. So football players who come to camp fit and used to the heat are at low risk of heatstroke during two-a-days.

Key Risk Factors for Heat Intolerance in Football

- Days 1-2 of two-a-days
- Temperatures over 80°F, 40% RH
- Unacclimated
- Dehydrated
- Out of shape
- Warrior mentality
- Overweight
- Supplements

Uniform Penalty: The football uniform insulates the player, making it tougher to shed heat. As more equipment is added — from shorts and shirt to practice pads and helmet to full uniform — players heat up faster, get hotter, and cool slower.

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Message From the President


Ronnie Barnes

As we go into the 2002 season, athletic trainers are more vigilant than ever when it comes to monitoring their players for symptoms of heat illness and dehydration. The tragic events of last summer were strong reminders that we cannot let down our guard when it comes to preventing heat-related injuries.

In that spirit, we must work harder than ever before to arm our selves and our athletes with a continuous and comprehensive stream of information about the dangers of dehydration and heat illness.

I am pleased to say that we have been working hard on this end with our partners at the Gatorade Sports Science Institute to produce an educational program called "Tackling the Heat: A Game Plan for Competing Safely." It will provide you with functional tools to prevent dehydration and heat illness through proper hydration. (Stay tuned to the NATA for more details.)

We've also been working with the NFL, engaging their members in a dialogue on how we can come together to make our sport safer.

What can you do to help? Familiarize yourself with the NATA position statement on Fluid Replacement for Athletes and create a hydration action plan for your athletes. Stay current on the signs and symptoms of dehydration and heat illness. Identify at-risk athletes and watch them carefully for warning signs. And encourage your athletes to speak up and tell you if they are feeling ill or are experiencing any signs of dehydration.

While we have little control over many of the risks and dangers of our sport, with your help we can help minimize dehydration and heat illness, which is 100 percent preventable.

News and Notes

Award Winners

PFATS recognized the following professionals at the 2002 NFL Combine for their work in the field of sports medicine:

- **Bertram Zarins**, MD, team physician for the New England Patriots, received the *Jerry Rhea "Hawk" Award*. It is sponsored by PFATS and presented to the NFL team doctor who has made the greatest contributions to both the NFL and the profession of athletic training.
- **Jim Whitesel**, formerly the head athletic trainer for the Seattle Seahawks, received the *Cain Fain Memorial Award*. It is sponsored by the NFL Team Physicians Society and presented to the PFATS member who best reflects the virtues of a certified athletic trainer and the highest level of professionalism.
- **George Anderson**, formerly the head athletic trainer for the Oakland Raiders, received the Distinguished PFATS Alumni Award.

New Faces

- Baltimore Ravens: **Mark Teeples**, Assistant Athletic Trainer
- Buffalo Bills: **Chris Fischetti**, Assistant Athletic Trainer
- Carolina Panthers: **Ryan Vermillion**, Head Athletic Trainer, **Mark Shermansky**, Assistant Athletic Trainer
- Houston Texans: Assistant Athletic Trainers **Tom Colt** and **Jon Ishop**
- Kansas City Chiefs: **Keith Abrams**, Assistant Athletic Trainer
- Minnesota Vikings: **Nate Stier**, Assistant Athletic Trainer
- New England Patriots: **Jim Whalen**, Head Athletic Trainer
- Tampa Bay Buccaneers: Assistant Athletic Trainers, **Scott Trulock** and **Pat Jernigan**
- Washington Redskins: **Dean Kleinschmidt**, Head Athletic Trainer, **Larry Hess**, Assistant Athletic Trainer

NFL Athletic Training Staff of the Year

Head Athletic Trainer **Lindsy McLean** and Assistant Athletic Trainers **Todd Lazenby** and **Jeff Tanaka** of the San Francisco 49ers have been named the 2001 NFL Athletic Training Staff of the Year. They became the 17th staff to be recognized by their peers in receiving this prestigious award.


San Francisco 49ers Athletic Trainers Jeff Tanaka (left) Lindsy McLean (center) and Todd Lazenby (right)

Ilio DiPaolo Scholarship Fund-Giving back to Kids and Community

Buffalo Bills Head Athletic Trainer Bud Carpenter takes seriously the concept of "giving back to the community." Active in many of his local charities, he donates his time to supporting educational initiatives including Drug Abuse Resistance Education (DARE), the Make-A-Wish Foundation and Kids Escaping Drugs. He is a member of the board of directors for Hunter's Hope Foundation and is also very proud of his work as the founder and president of the Ilio DiPaolo Scholarship Fund.


Bud Carpenter

He created the Scholarship Fund six years ago to honor legendary professional wrestler Ilio DiPaolo, who was killed in an automobile accident. His goal was to use the Fund to carry on DiPaolo's tradition of helping local children and high school athletes in Western New York.

While the fund's original mission was to provide financial assistance to local high school wrestlers, it has since grown in scope to cover several other worthy organizations. Today, the fund supplies much-needed money to the Center for Handicapped children — and provides more than $300,000 to Children's Hospital and $500,000 throughout Western New York.

"We are fortunate to have the support of local corporate sponsors including the Buffalo Bills, that share in the same ideals as DiPaolo and the Scholarship Fund," says Carpenter. "With their continued support, we will be able to provide money to the children and organizations of Western New York for many years to come."

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Editorial Advisors: Todd Lazenby, ATC, San Francisco 49ers
John Norwig, ATC, Pittsburgh Steelers
Joe Recknagel, ATC, Detroit Lions
Scott Trulock, MA, ATC, Tampa Bay Buccaneers

Managing Editor: Miles Rush, MS, ATC, CSCS
Editor: Lorri Christou

Direct Inquiries to: Miles Rush, MS, ATC, CSCS
Fleishman-Hillard, Inc.
875 North Michigan Avenue, Suite 3300
Chicago, IL 60611
312.751.3733

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Neuro Mobility and the Treatment of Nerve Root Injuries

Todd Lazenby, MA, ATC

Frustration is often the operative word when it comes to the rehabilitation of a nerve root injury. The normal course of treatment — which includes non-steroidal anti-inflammatory drugs (NSAIDs), modalities such as electrical stimulation, ultrasound, heat, ice, massage and strengthening exercises for the neck, shoulder girdle and upper extremities — often brings about less than optimal results. It seems as if rest is one of the only modalities that truly works, but time is a luxury that is rare in the National Football League.

San Francisco 49ers assistant athletic trainer Todd Lazenby performs Median nerve tests ULNT1 & 2A on defensive tackle Bobby Setzer.

Neurodynamics

A relatively new concept of therapeutic treatment for nerves is known as Neurodynamics. Very simply, the idea behind Neurodynamics is that the nervous system is a continuum with the physical abilities to "communicate via electrochemical means.[1]" The concept of a therapeutic treatment for nerves has actually been around since the 1880's, when it was referred to as nerve stretching,[2] but it was not really developed or applied in manual therapy until about 25 years ago by Australian Physiotherapist David Butler. Butler re-introduced the concept into the United States when he published his book *Mobilisation of the Nervous System* in 1991. Over the last year the methods described and taught by Butler have become an integral part of the San Francisco 49ers athletic training staff's treatment protocol for stingers, brachial plexus strains, nerve root irritation, nerve contusions as well as many lumbar and lower extremity issues.

> "Very simply, the idea behind Neurodynamics is that the nervous system is a continuum with specific physical properties."

Properties of the Nervous System

The nervous system utilizes mechanical, electrical and chemical properties to execute its function in the body. To illustrate the mechanical quality of nerve tissue, consider what happens during athletic activity. When a football is thrown, for instance, elbow flexion and wrist extension occur simultaneously, both stretching and compressing the Ulnar nerve. The nerve must possess elasticity to accommodate the changes in length and resist pressure changes. This is also illustrated along the spinal canal, where the length of the spinal cord can increase up to 10 centimeters from the resting length to when the spine is flexed.

The health of the nerve is dependent upon the ability of its cell, the neuron, to nourish itself with axoplasm. Axoplasm surrounds the neurons and provides a medium for the transmission of signals to other neurons via neurotransmitters. If the nerve becomes ischemic via entrapment, the viscosity of the axoplasm increases from its normal consistency (5x greater than water) to a much thicker, gel-like substance. This decreases normal neurological transmission and increases the chance for chronic pain through abnormal impulse generation.[2]

The chemical property or health of the neuron is therefore dependent upon the axoplasm, whose viscosity is dependent upon the ability of the nerve to glide and move. If a nerve is gliding normally, the axoplasmic flow is maintained and the health of the system is ensured. The function of movement also relates directly to the ability of the nerve to conduct electrical impulses, which is the third component of Neurodynamics.

Blood Flow

The nervous system is very "blood thirsty" and neurons can demand as much as 30 percent of the total oxygen pumped from the heart. A lack of blood flow can adversely affect the function of the nervous tissue and an increase in the length of a single peripheral nerve by as little as eight percent is enough to starve that nerve of blood and oxygen. However, based on the fact that normal nerve tissues act as a continuum, as much as a 20 percent change in length will not result in ischemia as the system pulls movement from different areas and directions to compensate.[2] So very simplistically, the importance of movement for a nerve is paramount. Any impingement on the nerve, whether from a disc herniation, spur, soft tissue hematoma, etc., can compromise nerve function.

Testing for Neurological Entrapment

Injuries to the brachial plexus, nerve roots and other tissues throughout the upper body are common in football. Neurological disorders in the upper body will often manifest themselves in symptoms along the upper trunk or anywhere along the distribution of the median, ulnar, radial nerves, or any combination thereof.

To differentiate which nerve is involved, it is necessary to perform Upper Limb Neurodynamic Tests (ULNT) for each nerve tract. The tests should first be performed on the uninvolved side to allow the patient to become comfortable with the testing procedure. When testing the involved side, it is important to note at what point in the range of motion symptoms occur and how severe those symptoms are. Dynamically adding in cervical lateral flexion towards the uninvolved side will also increase the tension placed upon the nerve.

Upper Body Tests

We use three common upper limb tests as described by Butler.[2] They include the following nerve tests:

- The median tests (ULNT1) includes shoulder abduction, wrist and finger extension, forearm supination, shoulder external rotation and elbow extension. The addition of shoulder depression to the test (ULNT2A) increases the tension placed upon the plexus, and nerve roots and tract.
- The radial test (ULNT2B) involves shoulder depression, elbow extension, shoulder internal rotation, wrist and thumb flexion and shoulder abduction.
- The ulnar test (ULNT3) requires shoulder girdle depression, shoulder external rotation,

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Fighting Heatstroke in Football

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Heatstroke Habitus: Overweight players are at higher risk of heatstroke. Extra fat is an extra load, increasing heat production in workouts. In a risky tipping of the scales, the NFL now has nearly 300 players who weigh 300 pounds or more, six times as many as a decade ago. And extra fat is not the only bulk problem. When a 270-pound player adds 30 pounds of muscle, he can generate sharply more heat, but does not add enough extra surface area to shed that extra heat. So huge lineman can be heat bombs.

Warrior Mentality: A wag once said that football is men playing at war. In any case, football is not for sissies and the culture of the game breeds a warrior mentality. The victims of heatstroke are often described as "the hardest worker" or "determined to prove himself." During a tough practice on a hot day, the never-give-up mentality can work against a player. That's why coaches, athletic trainers and team physicians must always be on the alert for signs of heat illness.

Tough Coach: Sometimes the coach is the warrior, pushing his players to the limit. As coach Howard Schnellenberger said when questioned about his two-a-day practices at the University of Oklahoma, "Everybody that's ever played the game of football has to go through the dog days of summer, has to throw up and pass out and do all those things that football players have done for 100 years." Football is a tough sport, but the best approach is to become tough gradually and avoid dehydration, nausea and fainting, the things that weaken football players, making them more susceptible to life-threatening problems.

Supplements: Stimulants speed the rate of heat buildup, so any product that speeds players up heats them up. Amphetamine and cocaine are the most dangerous, but herbal ephedra is the most prevalent. Many dietary supplements tout ephedra, often with caffeine, for weight loss or quick energy. But ephedra has many risks — including death from heart attack or stroke — and it increases the risk of heatstroke. Heatstroke risk is compounded if the football player is also on a medication that may blunt sweating, like antihistamines, anticholinergics or tricyclics for depression.

Tennessee Titans Assistant Athletic Trainer Geoffrey Kaplan making sure Titans defensive end Jevon Kearse stays well hydrated.

Recognition of Heatstroke

Heat exhaustion and heat cramping are of course also heat illnesses, but heatstroke is the only heat illness that can kill a football player. Heatstroke sometimes seems to hit with surprising speed. When this happens, a common theme of bewildered staff is, "But he got lots of fluids." The common misconception is that hydration prevents heatstroke. The truth is that avoiding dehydration is critical but not sufficient to prevent heatstroke in football. This truth becomes clear on pondering the 10 risk factors above — the many streams that can make a river.

Actually, compared to the other common causes of collapse onfield, heatstroke is usually slow to develop and the vigilant coach or athletic trainer can recognize the early warning signs and avoid the worst. A watchword is that heatstroke is always a specter during high-intensity drills on a hot, humid day, especially in a fat, unfit, unacclimated, dehydrated football player wearing full gear. Another watchword is to stress hydration but at the same time think beyond hydration.

Early signs of impending heatstroke may include irritability, confusion, apathy, belligerence, emotional instability or irrational behavior. The coach may be the first to note that a player, heating up, can no longer think clearly or follow the play. Giddiness, undue fatigue, and vomiting can also be early signs. Paradoxical chills and goosebumps signal shutdown of the skin circulation, which results in an even faster rise in body temperature. The player may hyperventilate — for the same reason a dog pants — to shed head; this can cause tingling of the fingers, what some players have complained of before collapse. Incoordination and staggering (running like a puppet on a string) are late signs, followed by collapse with seizure and/or coma. At this point of collapse and coma, as in all three players who died last summer, core body temperature can be 108°F or higher. Early diagnosis and fast therapy can save lives.

Avoiding Disaster

Covered above were 10 key risk factors for heatstroke in football. Here are 10 practical ways to help prevent heatstroke.

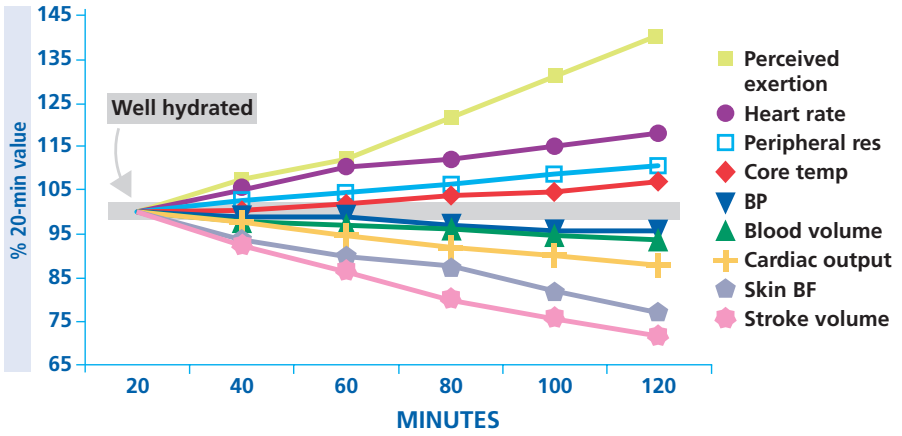
Keep Them Cool: The cooler they stay, the better they play. Take frequent breaks for cooling. Keep fluids handy. Provide shade, ice

The NFL Bans Ephedrine

The National Football League (NFL) recently joined the International Olympic Committee and National Athletic Trainers' Association to prohibit the use of dietary supplements containing Ephedrine (or other ephedrine alkaloids such as ephedra or methylephedrine). The ban, which will be strictly enforced with the start of this summer's training camps, also prohibits NFL players from endorsing companies who manufacture supplements with ephedrine or its related compounds.

These drugs, which produce a stimulant-like effect, harbor potentially-dangerous side effects for athletes who take them to increase their energy levels and lose excess weight. That includes dizziness, headache, gastrointestinal distress, heart palpitations and heart attack, stroke, seizures, psychosis and even death. Ephedrine can also raise heat production and body temperature, putting athletes at greater risk for heat-related illness when exercising in hot environments.

The unavoidable negative consequences of dehydration



65% VO_2 max cycling; 35°C; -4.9% BW; from Coyle /*JSM* 19:S121-S124, 1998.

water, and misting fans for rest breaks. As heat rises, reduce practice pace and duration and increase rest breaks. Have players sit in cold tubs right after practice. Hold practices earlier or later, spread them out with more time between, time for rest, recovery and cooling. On the worst days, practice in an air-conditioned venue.

Hydration is Key: Proper hydration helps fend off heatstroke. Thirst kicks in too late — after the player begins to dehydrate — and shuts off too early if a player quaffs only water. Players should drink on schedule: before, during and after workouts. A sports drink like Gatorade beats pure water because it has sugars to fuel muscles and brain and sodium to hold fluid in the body and help replace sweat losses.

Be Prepared: High heat and humidity can overwhelm even properly hydrated players. A few days of moderate physical activity in the heat, lasting from 60 to 90 minutes, can jump-start heat acclimation. Do this just before summer camp starts.

Bird-dog the Big Guys: Focus on the high-risk players. Spot subtle signs of physical or cognitive decline. Any weight loss the first few days of summer camp is fluid loss, not fat loss. Dizziness and drop in blood pressure on standing up in the morning signal fluid and sodium depletion. Urine should look like lemonade, not apple juice. Monitor weight before and after practice and the next morning. Morning weight should be back up, close to that of the prior morning — and body temperature should be normal — before the player takes the field. When in doubt, hold them out.

> "Lack of acclimation is a cardinal predictor of heat illness in football two-a-days."

Uniform Concerns: Limit use of full pads and helmet in high heat or humidity, to avoid turning players into heat bombs. It makes health sense to suit-up in stages, over the first few days of summer camp. For example, no pads the first day; helmet only the second day; shoulder pads and jersey the third day. To further cut the risk of heatstroke, remove helmet and pads for any conditioning runs.

Counter the Culture: Some players are over-motivated by pride and/or over-driven by tough coaches. They push the limits, believing there are none. They ignore warning signs. You have to get them off the field and cool them down. Don't let the warrior call the shots.

Train Them, Don't Strain Them: Start slow. Players can not be expected to start full tilt in stifling heat. Other than massive bleeding, exercising all-out in extreme heat is the greatest strain that can be placed on the human cardiovascular system. Workout intensity and duration should start low and build slow. Don't drive them halfway to heaven on the first day.

Monitor Medications: Stimulants like ephedra increase the risk of heatstroke. So do some other drugs and medicines, as covered above. Even creatine and protein powders can pose a risk of dehydration and so heat illness. Make sure every player shows you everything he takes, including herbal and dietary supplements.

Off-field Behavior: Monitor off-field behavior too. Players who are not sleeping well or who have recently been ill, especially with vomiting or diarrhea, or with a fever, are more prone to heatstroke. The same applies to those who take diuretics, consume large doses of caffeine or drink too much alcohol.

Cooling Cues: The big guys, those players at high risk of heatstroke, may benefit from pre-cooling before practice and hot-weather games. Research shows that time in a cold bath will slightly reduce core temperature, increasing the safety margin for heat illness. Another benefit may be improved athletic performance in hot weather. Using cold towels or splashing cold water on the face, head and neck provides a psychological boost but little physiological benefit. Better to be wet inside than outside. If a player collapses, a rectal thermometer is the only way to get an accurate core temperature. In the face of heatstroke, dump the player immediately into a tub of ice water on the sideline. A large plastic wading pool or the like will suffice, so the body is immersed from shoulders to hip joints. In heatstroke, body and brain cells die fast, so minutes count. The life-saving adage is: Cool first, transport second!

Heat-Illness Workshop

The 2002 Combine provided the setting for a heat-illness workshop lead by the NFL Physicians Society and attended by over 90 athletic trainers from the NFL. A result of the heat-illness summit organized by NFL Commissioner **Paul Tagliabue** that featured several PFATS members last August, this most recent session included lectures from **Bob Murray**, PhD, Director of the Gatorade Sports Science Institute, **Margaret Kolka**, PhD, Assistant Chief, Thermal and Mountain Medicine Division, US Army Research Institute Of Environmental Medicine and **John Lombardo**, MD, Team Physician at The Ohio State University and the NFL Advisor on Anabolic Steroids and Dietary Supplements. Topics discussed included heat exhaustion and dehydration, fluid and electrolyte replacement and dietary supplements.

Eichner is a professor of medicine at the University of Oklahoma Medical Center and team internist for the University of Oklahoma football team.

New Developments In The Evaluation of Sports-Related Concussion

Mark Lovell, PhD, ABPN, John Norwig, MEd, ATC, Ryan Grove MS, ATC, Michael Collins, PhD, Joseph Maroon, MD, James Bradley, MD, Anthony Yates, MD

During the 1980's and 1990's recovery from sports-related Mild Traumatic Brain Injury (concussion) was poorly understood. The lack of a strong scientific foundation caused many groups to establish concussion management guidelines based on opinion rather than systematic research. As a result, sports-related concussion is now one of the most hotly debated issues in professional sports. Concern about when it is safe to return an athlete to the playing field following injury has inspired a league-wide effort around early diagnosis of injury and prevention of injuries that are more severe. This article will review new developments in the diagnosis of concussion and address "return to play" issues in the injured athlete.

Pittsburgh Steelers linebacker Kendrell Bell tackles Jacksonville Jaguars running back Stacey Mack. The high-speed collisions that occur in the NFL can often result in concussion.

On-Field Identification

It can be difficult and complicated to identify concussion on the field. The signs and symptoms of the injury may be subtle. An athlete may not show the more obvious indications of injury, such as loss of consciousness or incoordination. He may be reluctant to report initial symptoms such as headache for fear of being removed from the game. Although the form of on-field evaluation may vary between teams, we suggest developing and using a standard sideline evaluation approach that includes a brief mental status examination as well as questions regarding symptoms.

Evaluate the athlete for any confusion and memory loss around events occurring just before the injury (retrograde amnesia) and right after (anterograde amnesia). If an athlete reports symptoms, question him about complaints of headaches, visual changes, nausea, dizziness and balance dysfunction. It is important to emphasize that the absence, presence and duration of these signs and symptoms are important in determining the seriousness of the injury. Those that clear within seconds or minutes usually mark a milder injury — those that last longer signify something more severe.

Neuropsychological Testing

As awareness grows around concussion and its potentially adverse consequences, an increasing number of NFL teams are doing baseline neuropsychological testing. The Pittsburgh Steelers led the pack in 1993, when they started testing using "paper and pencil" procedures. They tested and re-tested injured athletes, comparing results to their pre-season level of functioning.

The Pittsburgh Steelers Program

A large step forward in the development of more effective concussion management techniques, traditional neuropsychological testing has proven to be time consuming, costly and lacking of the sensitivity necessary to detect mild injuries. These limitations, coupled with the widespread proliferation of the microcomputer, motivated the Pittsburgh Steelers medical staff to develop computer-based neuropsychological testing procedures in the mid-1990's.

Computer-based testing procedures have a number of advantages over the more traditional approach:

- Computers allow large numbers of athletes to be evaluated with minimal manpower. An entire football team can be assessed within a reasonable time period, creating less disruption to the teams' schedule.
- Data acquired through testing can be more easily stored and accessed on a computer at a later date (e.g. following injury).
- Computers promote more accurate measures around cognitive processes, such as reaction time and information processing speed. In fact, computerized assessment allows for the evaluation of response times that are accurate to the 1/100 of a second. (Traditional testing allows for accuracy only to one to two seconds.)
- Computers allow for the randomization of test stimuli, which helps improve the stability or reliability of test results across multiple evaluations. This minimizes the "practice effects" that naturally occur as an athlete becomes accustomed to taking a specific test. These practice effects have also clouded research results and presented obstacles for clinicians evaluating the true degree of neurocognitive deficit following injury.
- Computer-based evaluation promotes the unbiased evaluation of cognitive processes by eliminating error due to scoring or inter-rater reliability issues.

Recovery

Currently, grand-scale studies of concussion are underway both inside and outside of the NFL—the largest being done on neurocognitive recovery in athletes at the University of Pittsburgh with the Steelers' athletic training and medical staff. This ongoing study has resulted in the:

- Baseline testing of more than 3,000 high school, college and professional athletes.
- Post-concussion evaluation of more than 400 athletes.

One of the study's more important aspects has been the investigation of the

Signs and symptoms of concussion

Signs Observed By Staff	Symptoms Reported by Athlete
Appears to be dazed or stunned	*Headache*
Is confused about assignment	*Nausea*
Is unsure of game, score or opponent	*Balance problems or confusion*
Moves clumsily	*Double or fuzzy vision*
Answers questions slowly or forgets plays	*Sensitivity to light or noise*
Loses consciousness	*Feeling sluggish*
Shows behavior or personality change	*Felling foggy*
Forgets events prior to play (retrograde)	*Change in sleep pattern*
Forgets events after hit (anterograde)	*Concentration or memory problems*

relationship of on-field markers of concussion (i.e., loss of consciousness, confusion and amnesia) to recovery — as measured by computerized neuropsychological testing. Early results challenge traditionally held beliefs about the relative importance of on-field concussion markers. For example, loss of consciousness used to be the defining characteristic of concussion — its presence or absence often the basis of return to play decisions. Many physicians and athletic trainers believed that a loss of consciousness, however brief, denoted a more severe injury (compared to markers such as confusion or amnesia).

However, recent data shows that a brief loss of consciousness (seconds) does not necessarily result in poorer performance on neuropsychological testing or an increase in post-concussive symptoms when compared to amnesia.

- Concussed high school and college athletes who were observed to lose consciousness briefly did not perform more poorly on computerized neuropsychological testing one to seven days after injury (Figure 1).
- On the other hand, athletes who suffered either retrograde or anterograde amnesia (Figure 2) experienced significantly greater neuropsychological dysfunction and symptoms. That is, in comparison to a group of concussed athletes who did not experience amnesia.

Brain Imaging

Beyond neuropsychological testing, technologies have evolved that promise to be useful in the near future. In particular, functional brain imaging techniques such as Magnetic Resonance Imaging or Functional Magnetic Resonance Imaging (fMRI) are rapidly enhancing our scope of knowledge around recovery from concussion. Functional Magnetic Resonance Imaging for the evaluation of athletes has grown out of an awareness of the lack of sensitivity of more traditional anatomic brain imaging techniques such as computed axial tomography (CAT) and Magnetic Resonance Imaging (MRI). Although useful in identifying brain injury in more severe cases, CT and MRI scans are not often helpful in identifying the more subtle brain-related changes that are thought to occur on a metabolic rather than anatomic level.

Functional Magnetic Resonance Imaging has only recently developed as a viable tool for the assessment of neurological processes following mild traumatic brain injury. The technology is based on the measurement of specific correlates of brain activation, such as cerebral blood flow and oxygenation. Functional Magnetic Resonance Imaging involves no exposure to radiation and repeat evaluations can be undertaken with minimal risk. This allows the evaluation of changes in brain function that may occur with mild concussion and makes it possible to track the recovery process. Although still preliminary, initial data has been highly encouraging, demonstrating a correlation between fMRI abnormalities and recovery with our computerized neuropsychological test results.

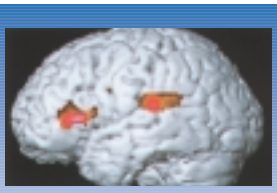
Case Study

As an example of the potential usefulness of fMRI and computerized neuropsychological testing technology, consider the case of a 17-year-old high school athlete who suffered a concussion. The initial signs of injury did not include loss of consciousness or noticeable amnesia. Rather, the athlete exhibited a brief period of confusion (approximately 30 seconds), accompanied by dizziness and sensitivity to light (photosensitivity). No immediate treatment was pursued.

The following morning however, she complained of a right temporal headache and mild fatigue. An evaluation, including computerized neuropsychological testing and an MRI, was subsequently conducted through the UPMC Sports Concussion Program. (The figure below shows the initial fMRI data 48 hours after the injury.) This scan reveals an abnormal pattern of brain activation in posterior brain areas.

Case Study:
48 hours post injury
(abnormal)

The athlete was then evaluated with an MRI and subject to neuropsychological testing eight days after the injury. Her fMRI scan had normalized as evidenced by activity in the frontal and temporal lobes of the brain. Her computerized neuropsychological test results were congruent with this resolution of abnormal patterns visible through fMRI. They demonstrated an initial decline at 48 hours after injury and a return to pre-baseline levels at eight days post-injury.



Case Study:
Eight days post injury
(normal)

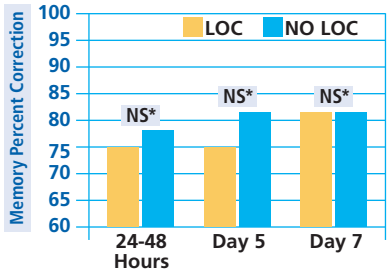
Conclusions and Future Directions

This article has focused on developments in the management of sports-related concussion, placing an emphasis on the fact that the clinical management of concussion is evolving rapidly and that we still have much to learn about both the short- and long-term consequences of injury.

The 1980's and 1990's were characterized by the proliferation and publication of concussion "guidelines" that failed to account for the high variability in the clinical presentation of the injury. Since then, these more standard guidelines have proven to be limited in terms of their usefulness, paving the way for a new more customized approach. It is based on the establishment of normal brain function prior to return to play. The diagnostic techniques outlined in this article will likely to continue to play an important role the clinical management of concussion as we move forward.

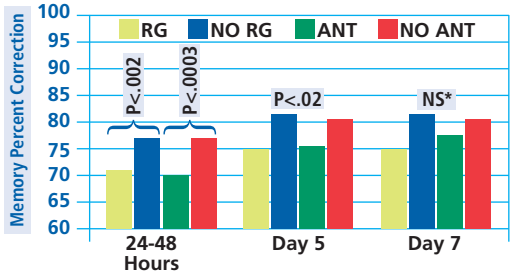
Lovell is the director and Collins is the assistant director of the University of Pittsburgh Medical Center Sports Concussion Program. Maroon, Bradley and Yates are team physicians with the Pittsburgh Steelers. Norwig is the head and Ryan is the assistant athletic trainer for the Pittsburgh Steelers.

FIG. 1 Brief Loss of Consciousness and Memory Recovery



No difference in memory (percent correct) between athletes with and without loss of consciousness

FIG. 2 Retrograde or Anterograde Amnesia and Memory Recovery



Significant differences in memory (percent correct) between athletes with and without on-field retrograde of anterograde amnesia.

NOTE: NS* = Non-Significant RG = Retrograde ANT = Anterograde

Neuro Mobility and the Treatment of Nerve Root Injuries

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shoulder abduction, elbow flexion, forearm pronation and wrist extension.

The testing is done from proximal to distal to simulate how the tension or the slack of the nerve is taken up during normal activity, but can be altered to simulate the sport-specific functions when the patient experiences symptoms. These tests not only are diagnostic measures to determine the amount of involvement, but also become a method of treatment for these injuries.

Treatment

When using these tests as mobilizations, it is important to perform high repetitions within a pain-free range of motion. The exercises are performed only to the point of discomfort, but you will note that range of motion will improve and the severity of the symptoms will diminish as the number of repetitions increase. The player should be retested daily to determine if progress is being made. This can be seen through an increase in range of motion before the symptoms occur and an overall decrease in the severity of symptoms.

Case Study

A 23-year-old rookie defensive lineman with a history of brachial plexus strains in college suffered four stingers during the course of the 2000 NFL season. The fourth injury occurred on December 23, 2000, the final game of the season, when he jammed his neck while hitting an opponent on kick-off coverage. Initially, the injury produced diffuse pain at the C7-T1 level with burning sensations down both arms. These symptoms were very similar to previous injuries except that he had prolonged upper extremity weakness with this event.

He was removed from the game and X-rays taken at the stadium were negative. Postgame examination revealed a resolution of the majority of symptoms. No sensory or motor deficits were present and he had a negative Spurling's sign. One month later, he contacted the athletic training staff complaining of chronic right upper trapezius and central neck pain with neck extension. An MRI revealed cervical stenosis at the C3-4, C4-5 and C5-6 levels — although there was no evidence of disc herniations. There was also foraminal narrowing due to spurring at the same levels.

Neurodynamic Testing and Treatment

Neurodynamic testing revealed increased sensitivity in the median, radial and ulnar nerve tracts. Three sets of 30 repetitions of the neural mobilization exercises as described above were performed, along with manual cervical strengthening in a pain-free range of motion. In addition, the player performed self-mobilizations as part of a home rehabilitation program.

Results

The athlete experienced immediate relief of right upper trapezius muscle symptoms after the initial treatment. Re-testing after one day of treatment in the training room and two days of self-treatment at home revealed a decrease in symptoms as seen by a greater pain-free range of motion. Over the next 17 days, utilization of the neurodynamic mobilizations — coupled with the cervical, scapular and shoulder girdle strengthening — resolved the right trapezius pain as well as his symptoms with cervical extension. He continued with the self-mobilizations as part of his conditioning program until he returned for training camp.

We feel incorporating Neurodynamics into this player's treatment protocol hastened the alleviation of the symptoms because:

- He was not taking any NSAIDs during the course of the treatment.
- He had no improvements in the symptoms with rest-only from January to March.
- Once we initiated the neurodynamic treatments, his symptoms decreased immediately and then resolved shortly thereafter.

Although released prior to the start of the 2001 season, the athlete was able to participate in all practices and scrimmages throughout training camp with no restrictions on his activity and without a recurrence of symptoms.

Conclusion

We have had great success incorporating these techniques into our rehabilitation programs. Although very effective in the treatment of brachial plexus disorders, we also use neurodynamic-based treatments with lumbar injuries or general muscle strains, as often times these injuries may have a neurological component. As with all treatment programs, the speed of the rehabilitation progression is dependent on the patient, but we feel that these techniques provide us an additional means to get our athletes back on the field as fast as possible.

Todd Lazenby is an assistant athletic trainer with the San Francisco 49ers.

References

[1]*Butler, David.* Mobilisation of the Nervous System: Diagnosis and Management of Physical Dysfunction of the Nervous System in a Pain Sciences and Clinical Reasoning Framework. *Continuing Education Course Workbook (15th ed.), 1991.*

[2]*Butler, David.* The Sensitive Nervous System. *Adelaide, Australia: Noigroup Publications, 2000.*

Please refer to the NeuroOrthopedic Institute's website at *www.noigroup.com* if you have questions regarding neurodynamics, continuing education courses or David Butler's book, *The Sensitive Nervous System*.

P.O. Box 386
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