ATHLETIC VENUES AS EXTREME ENVIRONMENTS

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Abstract: Artificial sports surfaces commonly employed in youth football, soccer, and tennis have long been suspect as causative for increased frequency of injuries to head, back, knees, and ankles, sometimes life-threatening or career-ending. In hot, sunny climates, the temperature characteristics of these surfaces contribute to the onset of heat stress syndrome and, in the most extreme cases, the collapse, seizures, coma and death associated with heat stroke. The inability of players and trainers to compensate for electrolyte and water imbalances increases the likelihood that young players early in a fall season may experience multiple signs of partial central nervous system impairment during normal athletic competition. The symptoms most likely to appear include changes in attention span, confusion, perceptual distortions, variability in reaction time, and diminished hand-eye coordination. The altered mental state can delay self-diagnosis, impair defense responses, and would be expected to produce an increased frequency of mechanical injury including traumatic concussion during contact sports such as football or soccer. The current paper is a brief summary of published literature addressing portions of this issue.

In our Institute the search for organisms adapting to extreme environments usually takes us to sites far removed from everyday life: high mountain alkaline lakes, acid mines deep in the earth, basalt lavas underneath the ocean, and the deserts of Chile, Africa, Australia, and the Antarctic. At each site life is most often threaten by extremes in one or more of six environmental characteristics: temperature, water deprivation, pressure, sheer forces, electrolyte imbalance, and pH. Interestingly, one of the most extreme environments on planet Earth occurs much closer to home: the artificial playing surfaces increasingly common in football, soccer, and tennis.

Since the first appearance of these surfaces players, trainers, coaches, and team physicians have all commented on the fundamental physics distinguishing artificial playing surfaces from well-watered grass or clay surfaces. The gradual change in surface density as a function of depth characteristic of water distribution in the chaotic structure of natural surfaces acts as a cushion softening the effects of either sudden direct impact or rapid shifts in direction. Artificial surfaces are comprised of a relatively soft upper layer and rigid underpinning. They lack the complexity of multiple soil grain sizes and interlocking root structures comprising natural grass fields. As a result, artificial surfaces have been implicated in career-ending knee, hip, and back injuries, as well as life-threatening head trauma. Now, increasing attention is being given to two other characteristics of artificial turf: excessive surface temperature and the spread of drug-resistant bacteria. In essence, these are alien, dry, barren, hard-packed wastelands exhibiting none of the familiar forest and veldt characteristics that have shaped the evolution of human physiology.

The most severe risks occur when young, student athletes play early in a season on hard, unyielding surfaces in hot afternoon sun and receive inadequate replacement of salt, water, and sugar. During a recent early season high school football match here in the Pasadena area, two teams were forced to play without ready access to electrolytes because the facilities prohibited all but water on the field. Apparently, at least one reason for the water-only policy is that spilled electrolytes are difficult to remove from the artificial turf. More than a dozen teenage athletes were escorted off the field for heat and surface related injuries. Surface temperatures were estimated to be between 140^{o}F and 160^{o}F, similar to those

measured on a nearby sister field.

This report is a summary of findings from the relatively few epidemiological studies available in the world literature.

Mechanical Injuries

A two- season (2001-2) survey of 5000 football players from 87 California high schools documented that injury rates were increased more than 50% on artificial surfaces compared to injuries on all surfaces. [1]

A survey of certified athletic trainers caring for more than 17,000 high school and college football players across three seasons revealed that 5.1% of the players sustained at least one concussion. Trainers reported that contact with artificial turf appears to be associated with more serious concussions than contact with natural grass. [2]

Replacing earlier foam-based turf with a new shredded rubber-based system does not reduce the force of impacts. In fact, some areas in the shredded rubber-based field were significantly compacted making some sites much harder than the foam-based surface. [3]

A 5 year prospective study of eight high school football teams documented that player–turf collision injuries were almost twice as common and muscle-tendon overload injuries were almost four times as common on artificial turf than on natural grass surfaces. [4]

In tests to understand the contribution of shoes and playing surfaces to knee injuries lowest peak torques occurred on grass compared to four types of artificial turf. The highest peak torques occurred when shoes designed for use on grass was used on artificial turf. [5]

One study has proposed that non-contact leg injuries (such as anterior cruciate ligament injuries) might be diminished by reducing shoe-surface traction. Measures recommended include ground watering and softening, playing during wetter winter months, use of natural grass surface, and use of boots with shorter cleats. [6]

Temperature Control

In Southern California temperatures as high as 160^{o}F have been reported on artificial turf surfaces. Infrared temperature measurements 125^{o}F were obtained on an artificial turf field on a late afternoon in October with an air temperature of only 75^{o}F. [7]

Between 1995 and 2001, 21 young football players died from heat stroke in the United States. The most common early manifestations of heat stroke are the result of cerebral edema. Danger signs include mild to moderate confusion, poor judgment, and diminished impulse control. [8] In athletic events, the confusion can easily be the direct cause of collateral mechanical injury since the afflicted athlete may be slow to recognize danger, forget previously learned safety techniques, and exhibit significant alterations in reaction times. Proper prevention is rapid replacement of salts (electrolytes) and water, and mechanical cooling including cold ice or ice water compresses to carotid arteries and jugular veins or even pouring cold ice water over a head or into a helmet.

In young adults, such confusion can be easily demonstrated with dehydration of less than 1-2% of body weight. There is no strong evidence that fluid loading prior to a game is a reliable preventive measure. Fluid and electrolyte loss and replacement cycles operate on a 10-15 minute time scale, while sugar replacement time scales are somewhat longer. As a result athletes need to stay ahead of the electrolyte

deficit curve by repeatedly replenishing with small quantities of replacement electrolytes during competition. Unfortunately, thirst signals to replace fluid loss may not be activated until we have lost fluid stores equivalent to ~2% of our weight. [9] To prevent heat stress and electrolyte disturbance, replacement solutions need to be immediately accessible, and student athletes, excited and involved in their competition, need to be repeatedly reminded by trainers and coaches to monitor their electrolyte replacement.

To avoid exacerbating early cerebral edema, fluid replacement should be a balanced solution of electrolytes, water, and sugar approximating the ratios normally found in blood. Common sports beverages such as Gatorade®, PowerAde®, and Pediolyte® while not perfect are a reasonable approximation of body electrolyte and sugar levels. [10] Attempts to correct the electrolyte disturbance with water alone are contraindicated since under certain physiological conditions this course can increase intracellular edema. [11, 12] Resultant transient elevations in intracranial pressure can hasten collapse and seizure activity.

Relative demands for sugar and electrolytes will vary between individual students and with ambient conditions. In the relatively high temperatures of Southern California, solutions may need to be altered to increase electrolyte concentrations and less importance given to replacing glucose stores. In such circumstances administration of classical Army/Navy "salt tablets" familiar to every bootcamp soldier for 100 years have proven useful in student athletes in preventing the appearance and progression of heat stress symptoms, but must be administered with significant fluid replacement.

While early detection of heat stroke can be problematic, the same is not true of exertional heat cramps. These painful, debilitating cramps are the most common obvious manifestation of heat stress and improper electrolyte replacement. The cramps are caused by significant alterations in the sodium, potassium, and calcium electrolyte balances controlling muscle contraction. Treatment again requires immediate replacement of electrolytes accompanied by mechanical massage of the affected muscle mass to restore circulation. [13]

Drug-resistant Bacteria

Once touted as 'clean', artificial turf football fields, have now been found to harbor true bacterial extremophiles: a potentially deadly staphylococcus bacterium mutant capable of producing antibiotic resistant biofilms in rubber-burn wounds that would most likely have been simple skid marks if acquired on natural grass or dirt surfaces. [14] Rubber-burn wounds at risk for infection will be found to contain small, round black pelts, the tarry residues from a hot, rubber-tire surface that most likely contain ground up pieces of skin and living bacteria. These are ideal substrates to form a bacterial biofilm impervious to antibiotics. Although minimal research has been completed on these injuries in a football/match setting, lessons learned from similar injuries in war zones would indicate that immediate cleaning and treatment of these wounds on the field is the safest course of action.

Summary

While high school and college parents, students, and coaches are often not invited into the political arena to determine choice of playing venues and schedules, they do have control over levels of preventive and reactive health care available on field. Many parents try to encourage pre-game fluid, sugar, and electrolyte consumption. Unfortunately, the delicate balance of temperature, salt, sugar, and water in the body changes rapidly during a match. Temperature control and particularly the replacement and balancing of sugar, water, and multiple types of salt needs to occur every 10 or 15 minutes during a contest.

Finally, I must point out that we owe much of what we have learned over the past 40 years about the necessity of returning the human body to its ancient balance of salt, water, and sugar to the early work of my Professor of Medicine, Robert Cade and his colleagues at the University of Florida. [15-19] His insights into the dangers for student athletes of untreated electrolyte imbalance and heat stress has unquestionably saved countless lives, prevented a wealth of secondary injuries, and improved the quality of life across the country. His death this past year is a great loss for the academic and sports communities. For a popular account of the development of electrolyte replacement techniques and the creation of the original Gatorade, see the short historical note published by A. Phillips-Han. [20]

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