EXTERNAL HEAT COOLANTS IN VARSITY FOOTBALL PLAYERS

by

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Chapter 1

INTRODUCTION

Heat stress is often a problem for athletes. Seasonal temperature in many parts of the United States including Kansas may exceed the 38°C (100°F) mark, making sports such as football extremely difficult for players in full uniform. Illness from heat exposure has taken its toll on a number of individuals with results varying from sickness to a more severe state, even death. This study was undertaken to examine problems with heat exposure encountered by football players.

The abilities of the human body to maintain its normal core temperature changes, which must occur for human life to function at a proper level, range from vasoconstriction when cold to vasodilation when hot. If the body is not able to remove the heat fast enough, the core temperature will rise. If it gets as high as 40°C (104°F), the chances of life are slim (3). Four methods by which heat may be lost from the body are: 1) convection, 2) conduction, 3) radiation, and 4) evaporation (2). Factors which may influence the maintenance or removal of heat from the body include clothing, humidity, and air passing over the body. Evaporation may remove as much as 50 percent of the total amount of heat from a resting body through the skin surface and respiration (2). Heat loss is proportional to the air speed over an exposed skin area. High humidity will lessen heat loss from the body through reduced evaporation. The amount of heat loss is important in maintaining body temperature at a level where normal body functions may be carried out. Evaporation is the means by which some of the greatest heat loss may be obtained. Immersing parts of the body into a cool water bath or constant covering of the body parts with ice towels may result in faster cooling and possibly more work potential. Techniques have been developed to help control the core temperature of men working in hot environments such as mines, steel mills, etc. Several different types of coolants can be applied to the body to help heat dissipation. A few ways in which heat can be extracted are: 1) body suits, which conduct water or air through tubes, 2) dry ice jackets, or 3) water cooled helmets which can remove heat from the head.

The elimination of heat from the body is increased by blood flow to the surface of the skin. Exposure to heat during work bouts for a period of 7 to 14 days causes this blood flow to the skin to increase, acclimatizing the person to heat. Acclimatization by an athlete is important by allowing sweat production to occur at a lower skin temperature level and more sweat to be produced per gland (11).

Problems exist with football players exposed to high levels of heat during the early part of the season in some areas of the United States. A high core temperature usually creates the major problem to the athlete because it reduces his performance ability. In order to maintain a stable core temperature, heat has to be extracted from the body. For effective body temperature regulation, heat loss must equal heat production.

Since football players have only a limited amount of time and are required to be mobile, one practical method to assist in heat dissipation could possibly be accomplished by placing ice towels around the athlete's head, neck, and waist. This method is practical due to the time factor involved and the amount of clothing worn. The heavy padding on the shoulders, head, and hip areas helps to lessen the amount of heat lost from the body during exercise.

The players are required to be available for competition at a moment's notice so the length of time that ice towels can be applied to the athlete may be short. With the short time duration, the industrial type coolants cannot be applied to a football situation. The player's pads cannot be removed thus eliminating the jump suit (circulating cool water through tubes) as a beneficial source of removing heat. The dry ice jacket creates a similar problem due to the necessary removal of clothing and pads to allow the jacket to control the temperature of the body surface. The mobility of the football player limits the extent of industrial type coolants that could be used for removing heat. The industrial situation differs due to the type of job that is done in the hot environment. The industrial worker is in an area for an extended period of time so that a type of coolant may be applied over a greater length of time. The industrial situation is a more controlled environment in which the body temperature can be lowered from the higher ranges during work. The football player has no such environment which may be altered as in the case of the industrial worker.

Statement of the Problem

The purpose of this study is to determine the body's ability to maintain the core temperature, heart rate (HR), and oxygen uptake ($\dot{V}O_2$) during heat stress situations. More specifically this study is to determine if any significant difference in body temperature can be affected by ice towels while in a heat stress situation of 40°C (104°F) with 40 percent relative humidity. Heat can be extracted from a person wearing a full football uniform by means of ice towels around the head, neck and waist areas.

Limitations

Certain factors which might have an effect on the results of this study should be noted:

1) subjects were limited to a small group.
2) the total time duration of 75 minutes was relatively short.
3) the work bouts produced on the football field were anaerobic in nature as compared to riding a bicycle ergometer at a constant work load

for 5 minutes which may have an aerobic effect on the individual.

Delimitation

The delimiting factor was that the selection of football players was from the 1975 Kansas State Varsity squad.

Definition of Terms

Acclimatization--Continuous repeated exposure to heat during physical activity to bring about a tolerance or an adjustment to the temperature level.

Core Rectal-Temperature--The point or center of the body in which the body temperature stabilizes at a constant resting level (7 cm past anal spinctor).

Electrocardiogram-ECG--Graphic tracing of the electrical activity of the heart muscle. Reflection from a trial and ventricular activity are shown on graphs which can be used to determine heart rate.

Heart Rate--Number of ventricular beats per minute.

Heat Stress--Environments ranging from 26^{o}-27^{o}C (78.8^{o}-79.8^{o}F) and higher, the normal threshold for sweating starts at 30^{o}-31^{o}C (86^{o}-87^{o}F), the extreme temperature zone begins at this level.

Ice Shock--An external method of cooling which tends to decrease the venous return with increased resistance to blood flow.

Metabolic Heat--Heat produced by the basal metabolic rate of the body which can combine with heat produced by muscle contraction during activity.

Oxyten Uptake ($\dot{V}O_2$)--is the volume of oxygen extracted from the inspired air, usually expressed in liters per minute.

Respiratory Quotient (RQ)--RQ is the ratio of carbon dioxide volume produced, divided by the oxygen volume utilized, expressed in parts which can be used to demonstrate the amount of fat and carbohydrate metabolism.

Standard Temperature Pressure, Dry (STPD)--The inspired air volume corrected from ambient air and expressed in liters per minute is the STPD value which is used to express the volume of oxygen extracted at $0^{o}C$ ($32^{o}F$), 760 mmHg with no water vapor present.

Sweat Rate Loss--The amount of body fluids lost--in grams--during the testing session. Expressed in grams per square meter of surface area per hour.

Chapter 2

REVIEW OF LITERATURE

This chapter reviews research related to heat stress situations. These studies are presented to show various methods in which heat exposure is kept at a lower level in all levels of physical work including industrial, aerospace, and athletic activities. Physiological parameters, which are recorded during the testing, deal primarily with core and skin temperatures, heart rate, sweat rate loss, and oxygen uptake. Two main areas discussed in the review of studies are: 1) general work and aerospace heat stress situations and 2) competition--football players competing in heat stress situations.

Industrial and Aerospace Heat Stress Situations

Various methods of cooling the body may increase the working capacity of the individual when dealing with industrial heat. The body temperature, which may increase during work in this hot environment, may rise as high as 40°C (104°F) or higher. Heat exposed illnesses may cause individual damage to the circulatory system or brain, with even the possibility of death.

Shavartz (23) showed one method of conduction cooling by placing dry ice in pockets of garments. When water ice changes from solid to liquid, it gains 80 kcal/kg of ice melted. When dry ice changes it gains 137 kcal/kg of gas going from -79°C to 35°C (-110°F to 95°F). Since dry ice gains more energy, it can be used more efficiently than water ice.

Konz and others (12) dealt with an external coolant from a jacket filled with dry ice for industrial workers. One subject was used during the experiment to determine how much heat is extracted from the person's body while in a heat chamber. Readings were taken every 10 minutes from an ECG, rectal probe for core temperature, and blood pressure. They concluded the ice would be more effective if it could be shaped to fit the human body. Petit et al. (19) first reported in the Belgian Mining Journal in 1966, the use of dry ice cooling. The garment was made out of leather and had four pockets in front and four pockets in the back. The pocket sizes were 10 X 10 X 3 cm. The pockets open at the top with approximately 50 holes on the inside surface, 3 mm in diameter, which permitted the carbon dioxide to flow close to the skin. Spherical dry ice, measuring 10 cm in diameter and 3 mm thick, was inserted into each pocket. Eight male subjects walked a treadmill for 20 minutes at six kilometer per hour at a 10 percent grade with and without the dry ice garment, in an environment of 46°C (114.8°F) dry bulb temperature and 50 percent relative humidity. The heart rate was 16 beats slower with the garment on, the oral temperature was 0.5°C (32.9°F) lower, and the skin temperature was 1.8°C

(35.24°F) lower. With a melting rate for the dry ice at 8.8 gm/min. No significant difference was found between the conditions of cooling vs. no cooling for measurement of oxygen consumed, rectal temperature, and sweat loss.

Webb and Annis (26) compared heat coolant systems of a space suit to allow comfort for the astronauts at the same time not over or under cooling them. A treadmill test was administered to the subjects with different speeds and grades to fit the subjects weight in order to achieve the desired metabolic rate. Subjects were weighed before and after the experiment to check oxygen intake, skin and core temperature, heart rate, and water loss. Water-cooled clothes were shown to reduce body heat, as well as slow sweat rate, cool skin temperature and remove metabolic heat.

Shavartz et al. (1974) circulated water through plastic tubes to ten different body regions, (neck, face, upper arm, hands, chest, back, thighs, lower leg and feet.) Three subjects were used in the experiment performing moderate work at 21.3°C (70.34°F) and in heat (49.3°C dry bulb, 31.4°C wet bulb), without any cooling other than that done to the above body regions. The face had the lowest temperature reduction (19 percent), while cooling of the back, chest, or thighs had the highest reductions (66 percent) in total body heat.

Rota and Todaro (21) compared two types of environment on the test subjects. Two series of tests were given in subsequent days with one hour of acclimatization given before the 20 minutes of testing began. The first series of thermal tests were in a neutral environment with the wall and the air temperature at 25°C (77°F), while the relative humidity was 40 percent and the wind speed 0.8045 kilometers per second (km/s) (0.5 miles per second). The athletes ran on the treadmill for a 20 minute period. The second series of tests were conducted on subjects with the walls and air temperature at 40°C (104°F) with 40 percent relative humidity and a wind speed of 2.4135 km/sec. (1.5 m/s). During the work periods, the following tests were recorded: 1) tympanic temperature; 2) skin temperature (chest, thigh, leg, and lower arm); 3) oxygen intake and carbon dioxide production; 4) heart rate; and 5) body weight before and after the test (nude). The heat loss and skin temperature were closely related between the two groups, both in a neutral environment during the first and tenth minute of work. The difference of temperatures was not significant. Ribisl and Zuti (20) established length of time for heat stress as mentioned earlier.

<u>Athletic Activity-Football players competing in heat stress situation</u>

Murphy (15) states an athlete is effected by dehydration when sweating, coupled with the lack of minerals and salt, and susceptible to cramps, heat exhaustion and heat stroke. In American football during the last 10 years alone, 46 deaths have been recorded due to heat stroke or heat exhaustion. Death from heat exposed illness ranks second only to that of head injuries. Minimal standards should be followed when athletes work in heat environment: 1) provide unlimited fluids during athletic activity; 2) salt tablets should be accompanied by large amounts of water; 3) when conditions warrant, measure heat and humidity so that practice can be altered. Quick replacement of lost body fluids and minerals is essential in hot weather work-outs.

Knochel (11) defines three major manifestations in a medical emergency as heat stroke; profound dysfunction of the central nervous system; a hot, dry skin; and a rectal temperature exceeding 40.6^{o}C (105^{o}F). Gradual heat acclimatization may lessen the chance of heat stress. A man can perform work in a hot climate without discomfort in hot weather. Persons who exercise in plastic suits are more susceptible to fatal heat stroke even with temperatures as low as 26.6^{o}C (80^{o}F). In response to an elevated body temperature hyperventilation occurs with heat stroke. A shift in potassium into cells occurs due to acute respiratory alkalois. This does not happen in the majority of heat stroke cases. Men training in hot climates may develop a deficiency in body potassium, due to losses in sweat. Three implications of potassium deficiency concerning athletes in training are: 1) can cause postural hypotension; 2) may impair glycogen synthesis in skeletal muscles; and 3) injury may occur to the skeletal muscles.

Fox states (7) from August, 1959 to October, 1962, seven heat stroke deaths were reported in high school players and five in college players. All players wore full football equipment. Five of the players who died were not able to have water during practice but were required to take salt tablets. This study was to quanitiate the effects of working in a football uniform with the temperature ranges from 23.33^{o}-25^{o}C (74^{o}-77^{o}F) with 31 to 55 percent relative humidity. Subjects ran on a motor driven treadmill at 9.654 kilometer per hour (6 mph) in both the football uniform and scrub suit for a 20 minute period. The final result, marked hyperthermia, while wearing the football uniform over that of the scrub suit, was a result of two factors: 1) the loss of over 50 percent of the evaporation surface area as a result of the additional clothing; and 2) the added weight of the uniform 6.44 kilograms (14.17 pounds) which increased the effective work load.

A serious hazard during strenous exercise is heat stroke. The committee on Nutritional Misinformation (4) reported that heat stroke was followed by a sudden collapse and loss of consciousness precipitated by physical exertion and inadequate fluid intake. The major factors causing heat strokes are high temperature, high humidity, poor body ventilation, and several hours of water deprivation preceding in tense physical activity. Good sound nutrition habits should be included during the practice periods to insure optimal health for the individuals. Individuals weighing 70 kilograms (154 pounds) lose about 1.419 liters (3 pints) of water each day by expired air, urine, sweat, and stools. With the loss of excessive fluids, sodium is also lost. The dehydration syndrome is characterized by loss of appetite and limited capacity for work. Dehydration causes increase in heart rate and body temperature even with moderate work. With three percent loss in body water, physiological changes impair performance. With five percent loss in body water, heat exhaustion becomes apparent and at seven percent loss of water, hallucinations occur, which is a dangerous sign. A ten percent loss is extremely hazardous and will lead to heat stroke. Without immediate treatment, death will occur. Athletes who try to lose weight by crash caloric restriction, or by drying out for early weigh in, then retain their usual weight for the contest, can cause permanent impairment of health and even death.

Virgin (25) describes the treatment for heat stroke which occurs to athletes who play forceful games during the summer months, is a predetermined treatment. The first part of treatment is a review of the athletes history followed by a physical examination, blood count, and a urine examination. Large doses of fluids and salt is given if there is no evidence of high blood pressure, kidney problem, or blood problems. Salt tablets should be taken depending upon the amount of weight loss after practice. Sodium and potassium are chemicals which are important in adequate amounts. Fifty athletes were tested over several months with a large number of solutions. It was discovered that salted apple juice with potassium, glucose, sodium, and other constituents were used to replace the loss of body fluids. To prevent heat prostration during game time, four important steps need to be followed, 1) prevent muscle cramping by maintaining the level of sodium in the body fluids, 2) when the temperature is excessive, cool the patient when he comes off the field, 3) to relieve the patient of the physical effects of deep, rapid breathing and rapid heart action, give him oxygen, and 4) replace the body fluids. The four treatments are administered when the athlete arrives at the bench with twenty liters of oxygen immediately given. Then a towel dipped in crushed ice is wrapped around his head and feet. One cup of liquid containing the chemical stated above is given if there is tendency towards cramping.

Olson (18) states the individual should know the importance of treatment to reduce the increased body temperature to decrease heat stress. The inability to keep the body temperature within normal limits involves a situation where the sweating mechanism fails and the elimination of body heat is inadequate. The main issue is to reduce the elevated body temperature as rapidly as possible. An effective means of treatment for heat stroke is the emersion of the persons body in cold water 48.33^{o}-52.22^{o}C (55-70^{o}F). During treatment, monitor the body temperature, vigorously massage the body segments to combat any vasoconstriction brought on by the cryotherapy to help in heat loss and to stimulate movement of cooled peripheral blood to deeper structures. Severe damage may occur to individuals who are not treated. Damage to the individual ranges from death, vascular permeability resulting in internal hemorrhaging, damage to cellular structure of sweat glands, central nervous system damage, liver cell death, destruction of cardic muscle, renal tubular damage, and metabolic acidosis resulting from liver dysfunction. Prevention may be the best solution to the problem of heat stroke. One of the most important factors is to remove the need for sweating by sleeping or resting in a cool environment periodically.

Heat injury may be viewed, Goldman (8) adds, as the result of an imbalance between the heat production associated with man's activity and the heat loss allowed in a given environment by the protective clothing and equipment he wears. He requires protection against heavy contact blows in the head, shoulders, kidneys, and groin areas requiring him to wear some form of body armor made from sturdy material. The heat transfer characteristics of a typical football uniform were measured using a heated copper manikin. The moisture permeability index can be determined by the ratio of evaporative cooling allowed by the uniform to that which would occur for an unrestricted wet surface. The football uniform evaluated consisted of a heavy undershirt, athletic supporter and woolen socks, plastic protective kidney, hip and shoulder pads, a standard football jersey and trousers, cleated shoes, and a plastic helmet. The cooper man simulated a 100 kilogram (220 pound) football player, 1.83 meter (6 foot) tall, with 2.22 square meters of body surface. If 35°C (95°F) is the skin temperature, then 23.89°C (75°F) ambient air temperature, he can only eliminate 30 kcal of heat by radiation and convection. An additional 480 kcal of heat must be lost by evaporation to avoid a rise in core temperature. To obtain this necessary 480 kcal of cooling in a uniform, 800 cc of sweat must be produced for cooling and perhaps twice that amount if the evaporation for cooling takes place on the surface of the uniform rather than at the skin surface. At best, about 180 kcal of evaporative cooling can be obtained, thus the player may have to store in his body 300 kcal per hour of heat. Improving the level of training or competition involved is about all that can be done to improve football clothing a player wears in heat stress situations.

Greenleaf (9) points out that sweat is hypotonic compared to man's blood. To investigate the influence of various levels of serum electrolyte concentration and osmolarity on the control of body temperature during exercise, 8 men were subjected to 3 levels of hydration: 1) hypohydration, 2) adlibitum control; and 3) hyperhydration. The men exercised for 70 minutes in the upright position on a bicycle ergometer at an average relative oxygen uptake of 49 percent of maximal oxygen uptake. Venous blood samples were taken before exercise, at 35 minutes into exercise, and at 70 minutes, just as completion. Samples were analyzed for sodium, potassium, chloride, osmolarity, pH, total protein, albumin and globulin concentrations. Rectal and mean skin temperatures were taken during rest, exercise, and recovery. The results suggest core temperature is not set by a volume mechanism, but is more directly related to the osmotic concentration. Calculations from sweat loss indicate that between 77-100 percent of the excessive rise in mean body temperature during exercise can be accounted for by reduction in sweating. The high correlation between osmolarity and core temperature is due to variation in sweat rate. Statistical evidence suggests the increased osmolarity acts mainly in two areas: 1) on the hypothalamus and other central temperature centers rather than at peripheral sites and 2) on the sweat glands themselves in the control of sweating during exercise.

Research is being done to help the athlete who has to compete in hot environments for lengthy periods of time. Murphy (15) has researched the effect of weight loss due to sweating on performance level in athletes. The maintenance of fluid volume to combat heat illness was studied by Londeree (13) and others to see if ingestion of fluids before, during, or after work has a significant effect.