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A Review of the Potential Implications of Hot and Humid Environmental Conditions on Soccer Match-Play Performance.

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Abstract

This paper identifies the physiological challenges faced by soccer players competing in hot and humid conditions. The metabolic demands of soccer, which consists of a combination of endurance activities and intermittent high intensity exercise, will cause a rise in core body temperature that has to be regulated through heat loss mechanisms. When conditions are hot and humid, these mechanisms may be compromised, resulting in high sweat rates, loss of electrolytes and the potential risk of dehydration and, in extreme cases, hyperthermia. When combined with a decrease in carbohydrate availability, which occurs when soccer is played in all environmental conditions, it is likely that players' performances will suffer, particularly during the latter stages of a match, or if extra-time is required. This performance-decrement will be evidenced by a decrease in work rate, skill and cognitive function both individually, and collectively. Potential solutions include a hydration strategy that uses nutrition and carbohydrate-electrolyte solutions to replace fluid, electrolytes and fuel that are depleted during match-play.

Key words: soccer; heat; humidity; dehydration; carbohydrate; fatigue.

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1. Introduction

Soccer is an endurance event, which includes intermittent bouts of high intensity activity [1]. Players cover distances of between 10 and 12 kilometres during a game, much of which is at a fast pace, including physical challenges, rapid acceleration and deceleration and intensive, fast sprints [1].

This places demands on the body which need to be fuelled by energy (predominately carbohydrate), which is stored in the muscle and liver as glycogen. The energy production needed for physical movement also produces heat that creates a rise in a player's core temperature. Temperature rises in proportion to the exercise intensity that the player experiences and will start during the pre match warm up, continue after the game starts, and reach a plateau which is determined by the work rate of the game [2]. At this point, normally 10-20 minutes after the start of a match, thermal equilibrium should occur when heat production matches heat loss. The loss of heat is essential if body temperature is to remain at a safe level, and it occurs through both convection and radiation and as a result of latent heat lost due to the evaporation of sweat from the skin. In the conditions normally faced by players in the English Premier League and other northern European Leagues, body temperature will rise to around 39 ^{o}C during a game, (from a resting value of around 37 ^{o}C), and remain at this level until the end of the match as the heat that is produced is lost by sweating, convection and radiation.

2. Discussion

2.1 Thermoregulation and hydration.

When matches are played in hot and humid conditions, the body's ability to lose heat is significantly impaired [1]. Venues for the 2014 Soccer World Cup experienced temperatures in excess of 30 ^{o}C, with humidity levels over 70%. In these conditions, it is much harder for body heat to be lost by radiation or convection, since there will be only a small temperature gradient between the skin and the air. Sweat evaporation will also be inhibited, due to the high moisture content as a result of the humidity. Sweat will drip from the body, rather than evaporate, and this is an inefficient means of losing heat. As a result of this combination of factors, and the continual production of heat from playing, body temperature will initially plateau, then quickly rise again. In hot and humid conditions, the body reacts to a rise in core temperature by increasing the sweat response, diverting blood to the skin to increase heat loss from convection and radiation. This results in an increase in sweat rate, and places an additional demand on cardiac output since blood is still required to transport oxygen to the working muscles. Increased heart rate at a standard work load is a common physiological response to exercise in hot and humid conditions [3].

Sweat rates of between 2 and 3 litres and hour could occur when playing soccer in hot, humid conditions [4], and studies have suggested that restricting dehydration to an equivalent of no more than 2% of body mass in soccer is acceptable [5]. This is equivalent to just 1.5 litres of sweat for a 75 kg player. In these conditions, it is possible that players will start to become dehydrated within half an hour of the start of a match, and certainly by half time, assuming that they were euhydrated prior to the start of the game. As sweat is lost, electrolytes,

particularly sodium and potassium, are depleted, changing the internal biochemistry of the body and potentially impairing energy production. Since electrolytes help to generate and conduct nerve impulses to the muscles and brain, any imbalance in their concentration as a result of sweating will impair or decrease the function of the muscles, cognition and nerve transmission. When sweat rates during exercise are high, replacing electrolytes is essential if optimal physical and mental performance is to continue. The rapid absorption of energy and fluid is vital if endurance performance is to be sustained, so frequent re-hydration during match-play is essential. Within the stomach and gut, the osmolality of a fluid will play a large part in determining how quickly absorption takes place. The presence of sodium is known to help transport fluid across the gut lining [6] ensuring that fluid that has been lost from sweating is replaced quickly, so that the performance limiting impact of dehydration is minimised. Furthermore, the presence of an optimal amount of electrolytes in fluid that is absorbed will ensure that electrolyte levels within the body are maintained during exercise.

If heat loss mechanisms are unable to function effectively due to the climatic conditions, body temperature will continue to increase. When it exceeds 40 ^{o}C, hyperthermia could occur, with symptoms such as dizziness, confusion and fatigue, and this could be fatal if allowed to continue, and the rise in body temperature becomes irreversible and catastrophic.

2.2 Work rate and energy expenditure.

The 90 minute duration of a soccer match means that players need to demonstrate good levels of endurance to sustain a high work rate [7]. The type of endurance experienced when playing soccer is very different to that required for other endurance activities, such as marathon running or long distance cycling. Soccer involves sustained exercise for 90 minutes, combined with intermittent bursts of high intensity activity [8]. Furthermore, these intermittent high intensity activities place high demands on the players' reserve of energy, glycogen. The stores of muscle and liver glycogen are obtained from carbohydrate that is consumed from eating or drinking, and will start to decrease from the moment that the pre-match warm up commences, until the end of the game. This will happen regardless of the climatic conditions. Depending on the nature and tempo of the game, it is quite possible that glycogen levels will be reduced to an extent that performance during the latter stages of a game, particularly the final 15-20 minutes, deteriorates. The major influencing factor on the depletion of energy stores is the work rate that a player sustains – a high work rate will lead to rapid use of energy. However this presents coaches with a dilemma, since maintaining a high work rate is critical to the successful outcome of matches. In tournaments such as the World Cup, where matches could enter extra time, avoiding glycogen depletion and maintaining work rate, is critical, and could have a fundamental impact on the final result. Utilising and understanding the optimal ways of re-fuelling during a game will help players replace the energy stores that are being used, and maintain soccer-specific endurance towards the end of a game, or in extra time.

2.3 Fatigue and physical performance

When conditions are hot, players will decide – either consciously or sub-consciously - to decrease their work rate so that energy and heat production are reduced, and body temperature decreases. If this is replicated across the team, work rate and performance will reduce. Fatigue of this sort is common during matches played in

cooler conditions but will be exacerbated in hot and humid conditions when a combination of dehydration and a lack of glycogen availability will cause fatigue. Anecdotal analysis of matches shows that the majority of goals are often scored during the latter stages of a game. For example, during the 2013-14 English Premier League season, a total of 223 goals were scored during the last 15 minutes of matches, compared with an average of 158 goals during each of the preceding 15 minute periods [9]. Whilst there are many factors behind this, including tactics and increased risk taking, it is suggested that physical and mental fatigue, caused by a combination of glycogen depletion and dehydration, will impact on performance and create more opportunities for goals to be scored. However if all other things remain equal, it is fair to assume that the team which remains properly fuelled and hydrated is more likely to be capable of sustaining a level of performance that results in goal scoring opportunities, rather than concessions.

2.4 Fatigue and cognition

In addition to the negative impact of dehydration and energy depletion on physical performance, it is also important to consider the effect that these factors have on mental performance and skill. As players fatigue – whether as a result of dehydration or a loss of energy – concentration and alertness will suffer [10]. Players will find it harder to concentrate, and to take correct decisions. Their ability to perform actions requiring a high degree of skill will also deteriorate, making accurate passing, tackling and shooting less likely. The capacity to take accurate free kicks, or even penalties (which will of course be critical in an end-of-match penalty shoot-out), will reduce.

2.5 Post-match recovery

Whether in hot or cool conditions, studies have shown that after a 90 minute soccer match, fluid and energy levels will have been reduced to a greater or less extent amongst players in a team [5, 11]. Adopting an efficient and effective recovery strategy is therefore critical, especially in a tournament such as a World Cup, where there is a need to train and play again within a relatively short time period. Replacing fluid and fuel that has been used during a game is essential, and scientific studies have shown that players will optimise their recovery if this occurs as soon as possible after a match has ended [8]. Failure to adequately focus on recovery will increase the likelihood of players commencing their next match or training session with sub-optimal fuel or fluid reserves, consequently resulting in early fatigue and a greater risk of injury. Whilst there are many causes of injury in soccer, it has been suggested that these include dehydration and low stores of carbohydrate [12].

3. Summary

In all sport, the difference between success and failure, especially at the highest level, is very small. In soccer, there has sometimes been a culture which has assumed that a combination of talented players and good coaching will suffice, and lead to success. However whilst good talent and coaching are essential, the global growth of the game, and the emergence of more nations where talent identification and development programmes are producing a steady stream of outstanding players, taking additional steps to enhance performance is fundamental to success. Since there is strong evidence to suggest that losses of fluid and fuel are detrimental to performance

in soccer played at any level, or in any environment, it is sensible to assume that those who coach, develop and play soccer will do all that they can to minimise the impact of fluid and fuel loss on performance. Appropriate pre-match preparation is essential to this goal, staying hydrated and consuming a diet where the majority of energy comes from carbohydrate. During a match, consuming solid foods is not recommended, but scientific studies have shown that carbohydrate-electrolyte solutions containing an optimal mix of carbohydrate, fluid and electrolytes, will provide an easy and rapid means of replacing the fuel, fluid and electrolytes which are lost when taking part in competitive sport [13]. Adopting a sensible recovery strategy after a match, to optimise replacement of fluid and fuel, will also ensure that players of all standards will be able to resume training, playing and their daily lives without feeling fatigued from the game they have just played.

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