Title: Half-time strategies to enhance second half performance in team sports players: A review

Running title: Half-time strategies

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ABSTRACT

The competitive demands of numerous intermittent team sports require that two consecutive periods of play are separated by a half-time break. Typically, half-time allows players to: return to the changing rooms, temporarily relax from the cognitive demands of the first half of match-play, rehydrate, re-fuel, attend to injury or equipment concerns, and to receive tactical instruction and coach feedback in preparation for the second half. These passive practices have been associated with physiological changes which impair physical and cognitive performance in the initial stages of the second half. An increased risk of injury has also been observed following half-time. On the day of competition, modification of half-time practices may therefore provide Sports Scientists and Strength and Conditioning Coaches with an opportunity to optimise second half performance. An overview of strategies that may benefit team sports athletes is presented; specifically, the efficacy of: heat maintenance strategies (including passive and active methods), hormonal priming (through video feedback), post-activation potentiation, and modified hydro-nutritional practices are discussed. A theoretical model of applying these strategies in a manner that compliments current practice is also presented.

Key words: Intermittent, fatigue, recovery, football, rugby

1. INTRODUCTION

A number of intermittent team sports, such as Association football (soccer), rugby, Gaelic sports (e.g., Gaelic football and hurling), field hockey and Australian rules football are played over consecutive periods (normally 30-45 min durations) that are separated by a temporary pause in play at the mid-way point; a period known as half-time. While the regulations of the various sports dictate the practices which can be performed during half-time, empirical observations highlight that players primarily aim to release mentally from the cognitive demands of the first half of match-play, rehydrate and re-fuel, attend to injury or equipment concerns, engage in personal reflection and to receive tactical instruction and coach feedback in preparation for the second half. Indeed, Towlson et al. [1] reported that soccer players primarily return to a dressing room to receive tactical discussion, provision of medical treatment and consumption of nutritional ergogenic aids during the half-time break.

Although often considered crucial for primarily tactical reasons, physiologically, half-time can be viewed as a recovery period following the previous bout of match-play, a preparatory period preceding subsequent competition, or a period of transition between the two halves [2]. Irrespective of the perceived function of this period, substantial physiological changes relating to acid-base balance [3], the glycaemic response [4-6] and muscle (T_m) and core temperature (T_{core}) changes [7-11] result from typically passive periods comparable in length to those observed during half-time (i.e., ~15 min).

Notably, reductions in performance during the initial phase of the second half of intermittent competition have been observed. For example, Mohr et al. [12] showed that as much as 20% of elite soccer players have their least intense 15-min period in a match during the initial part of the second half. Weston et al. [13] also highlighted that selected physical performances markers of soccer players and referees decreased between 45-60 min when compared to the first 15-min of soccer match-play. Similarly, in respect to cognitive performance, the increase in response accuracy observed during the first 30 min of intermittent exercise was attenuated in the first 15 min of the second half [14].

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In addition to the attenuated physical and cognitive performances observed after half-time, a significant increase in injury risk has been reported in the first 20 min of the second half [15]. Similarly, analysis of ten Premier League soccer matches has highlighted that of the injuries occurring in the second half, the greatest number of actions causing injury were elicited in the first 15 min of this period [16]. Interestingly, the perception of increased injury risk immediately after the half-time break is also shared by practitioners involved in the delivery of half-time activities for soccer players [1].

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Although a desire to enforce tactical superiority [17] and residual ergogenic effects resulting from the warm-up [18] have been cited to artificially elevate the pace of play in the initial stages of a match and thus influence subsequent comparisons to observations made during this interval [19], transient reductions in performance during the initial stages of the second half have been confirmed using a more robust statistical approach [19]. Furthermore, evidence also suggests that passive half-time practices are detrimental to the performance capacities of team sports players [8, 10, 11, 13, 19, 20]. Opportunities therefore exist to optimise the strategies employed during the half-time break with a view to enhancing preparedness for the second half of competition. However, as time pressures, cooperation of the coach/manager and concerns over impairing a player's psychological preparations have been cited as barriers to the use of specific ergogenic strategies during the half-time period [1], it is clear that any modification to half-time protocols must complement current practice.

The time-course of activities performed during a typical half-time period is outlined in Figure 1. Although likely to vary between different sports and according to individual team practices, Towlson et al. [1] reported that ~2 min of the soccer half-time period consists of player's making their way back to the changing rooms. Thereafter, although tactical de-briefing and medical and nutritional practices occupy the most time (~5 min), personal preparation, addressing playing kit/equipment concerns, receiving video feedback and player/coach interactions also occur during this time. Additionally, a ~3 min period of rewarm-up activities that are performed either on the pitch or within the stadia may precede the second half of soccer match-play [1].

***** INSERT FIGURE 1 NEAR HERE *****

In summary, given the transient changes in physical and cognitive performance that have been found to occur following the half-time break [8, 11-14, 19], and the evidence which suggests that the perception [1] and incidence [15, 16] of injury risk is elevated in the initial stages of the second half, half-time provides an additional opportunity on the day of a match to influence subsequent competitive performance. Therefore, the purpose of this review was two-fold; 1) to present an overview of the literature examining practices that may have application to the half-time strategies of players involved in team-sports, and 2) to provide a theoretical model of application of such strategies in the context of current practice.

2. Half-time strategies to enhance second half performance in team sports players

2.1 Heat maintenance strategies

A warm-up is a widely accepted practice prior to the start of nearly every athletic competition. Typically, this period includes varying intensities of exercise, dynamic stretching and technical practice in order to increase preparedness for subsequent activity. Although a number of non-temperature related mechanisms have been proposed to explain the ergogenic effects of the warm-up (e.g., elevated baseline oxygen consumption, PAP, increased mental preparedness [21, 22]), previous research has highlighted the role of muscle temperature (T_m) on performance.

Notably, Mohr et al. [8] observed initial elevations of both T_m and T_{core} during the first half of a soccer match, but during a passive half-time period both T_m and T_{core} dropped in excess of 1^0C. Sargeant [23] highlighted the importance of changes in T_m on subsequent performance by demonstrating that every 1°C reduction in T_m corresponded to a 3% reduction in lower body power output. Moreover, findings from studies reporting attenuated losses of T_m and concomitant protection of physical performance [8, 9, 20, 24] following an active re-warm-up further substantiate the importance of attenuating body temperature losses during half-time.

However, despite an acknowledgement that attenuating losses in body temperature impacts positively on subsequent exercise performance, intermittent sports players do not frequently use active re-warm up strategies in the applied setting [1]. Indeed, despite periods of warm-up preceding the first half of competition, only 58% of practitioners questioned have reported performing rewarm-up activities before the second half [1]. Time constraints, a lack of co-operation from the coach/manager and a perceived negative impact upon the psychological preparations of players have all been proposed as barriers to explain the inconsistent use of an active rewarm-up during the half-time period. Additionally, in sports such as rugby, where the number of collisions is high, considerable time may also be required for provision of medical attention at half-time. Therefore, half-time practices that are easily administered and which attenuate temperature loss and thus protect the temperature-related mechanisms that aid subsequent performance warrant further investigation.

2.1.1 Passive heat maintenance strategies

Passive heat maintenance is a method used to attenuate reductions in body temperature [25]. Passive heat maintenance involves the use of specific methods (e.g., heated clothing, outdoor survival jackets, and heating pads) which seek to attenuate heat loss. Such strategies are easily applied to the desired muscle groups to maintain T_m, and thus the temperature-mediated pathways which aid performance [7]. For example, when professional Rugby Union players applied a Blizzard ™ survival garment during a post warm-up recovery period, subsequent repeated sprint performance and lower body peak power outputs were greater than elicited in a control trial [7]. Additionally, the decline in lower body peak power output observed during the post warm-up recovery period was related (r=0.71) to the decline in T_{core} [7].

We recently observed that professional Rugby Union players who wore a Blizzard ™ survival jacket throughout a simulated half-time period experienced significantly lower reductions in T_{core} (-0.74 ± 0.08% vs. -1.54 ± 0.06%) over the 15 min period when compared to a passive condition [9]. Moreover, the drop in T_{core} over the simulated half-time was significantly associated with the reduction in peak power output at the start of subsequent exercise (r=0.632). Consequently, we purported that the passive heat maintenance strategy employed preserved the temperature-mediated pathways that contributed to the improved physical performances observed after the half-time break.

Maintenance of body temperature during the half-time period is therefore likely to attenuate decrements in subsequent performance; especially during the initial stages of subsequent exercise. Passive heat maintenance offers an effective and practical method for preserving body temperature, which helps to combat the decrements in performance which may occur through the loss of T_m. However, further research into strategies that seek to attenuate losses in body temperature and that have application to team sports players is warranted. Although encouraging players to wear specific garments is recommended and has proven beneficial [7, 9, 26], some players (e.g., those receiving injury treatments) may find this strategy restrictive when such clothing is worn during half-time. Therefore, other methods of maintaining body temperature during the half-time break should be considered; to date, the effects of increasing changing room temperatures (within tolerable limits) have not been examined.

2.1.2 Active heat maintenance strategies (half-time rewarm-up)

In soccer players, Mohr et al. [8] identified that moderate intensity running commencing after seven minutes of a half-time recovery period attenuated a 1.5°C reduction in T_m and a 2.4% decrement in mean sprint performance observed when passive control practices were employed. Additionally, the decrease in T_m at half-time was correlated to the reduction in sprint performance observed during the half-time break (r=0.60). More recently, Edholm et al. [20] reported similar magnitudes of sprint performance maintenance and attenuated losses in jump performance following a low-intensity half-time rewarm-up. Similarly, beneficial effects of active heat maintenance strategies have also been observed when intermittent agility exercise, whole body vibration, small sided games and lower body resistance exercises have been performed during half-time [10, 27].

Active rewarm-ups may also be of benefit to skilled, as well as physical performances, executed in the second half. For example, seven minutes of low/moderate intensity activity and light calisthenics performed towards the end of half-time improved performance during an actual match as less defensive high-intensity running, and more ball possession, was observed in the second half [20]. In support of the findings of Edholm et al. [20], skilled performance has also been reported to be maintained when technically focused half-time activities are performed [27].

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2.2 Post-activation potentiation (PAP)

The contractive history of a given muscle group can influence the ability of the same muscle group to produce force [28]. Where transient benefits to physical performance have been observed and attributed to PAP, the mechanisms are suggested to relate to an increased sensitivity of the actin-myosin myofilaments to Ca^{2+}, enhanced motor neuron recruitment, and/or a more favorable central input to the motor neuron [29]. Although a large body of research supports that muscular performance can be acutely enhanced by a preload stimulus [30], not all studies have demonstrated ergogenic effects as a number of factors have been found to modulate the PAP response (e.g., the strength of the participant, volume and type of the preload stimulus, and the duration of recovery between the preload stimulus and subsequent activity) [29]. However, when considering the potential application of PAP during the half-time period of team sports, the type of activities performed and the timing of the preload stimulus are likely to be of primary interest.

2.2.1 Timing between the preload stimulus and subsequent activity

The PAP response is a function of co-existing states of muscle fatigue and potentiation that are simultaneously present after a preload stimulus has been performed. Therefore, optimized recovery between the preload stimulus and the subsequent exercise favors an acute enhancement of subsequent performance as the decay in the rate of potentiation is less than the rate of decay of fatigue [31]. Additionally, the time demands associated with established half-time practices (Figure 1) are likely to influence the decision of whether to recommend performing a preload stimulus to players.

Recovery periods ranging from zero to 24 minutes have previously separated the conditioning exercise and the subsequent explosive activity. Notably, in a study incorporating professional rugby players and repeated assessments (i.e., baseline, ~15 s and every four minutes) of explosive activity for 24 minutes after the preload stimulus (three sets of three repetitions at 87% 1RM squat), Kilduff et al. [28] identified that power output, peak rate of force development and countermovement jump height were significantly elevated above baseline values at about eight minutes of recovery for the majority (i.e., 70%) of participants; a finding which has since been confirmed by a recent meta-analysis [30]. From a practical perspective, the transient nature of the PAP response means that the benefit to performance may be limited to the initial stages of a player's involvement in subsequent competition.

From studies where a heavy resistance exercise has been used to induce PAP, explosive lower body power production is consistently compromised immediately after the preload stimulus [30]. Therefore, should practitioners consider the use of a PAP stimulus during half-time, the preload stimulus should be timed relative to the start of match-play in order to minimise the effects that this transient reduction in performance may have upon subsequent competition.

2.2.2 Type of preload stimulus performed

The majority of studies examining the PAP phenomenon have employed heavy (i.e., 75-95% 1RM) resistance exercise as the preload stimulus [30]. However, practical considerations associated with the half-time practices of team sports players, including facilities access at away venues [1], mean that this approach may not be feasible during a game. Therefore, methods of inducing PAP which require less equipment and/or may be better tolerated by players and coaches on the day of competition are attractive alternatives. Ballistic activities such as weighted jumps are associated with the preferential recruitment of type 2 motor units [32], and therefore may be utilized as a PAP stimulus. Furthermore, plyometric exercise has also been found to potentiate sprint performance [33].

Improvements in jumping performance have been observed in the two minute period following a preload stimulus that included jumps against a resistance of 2% body mass (via a weighted vest) that were incorporated into a dynamic warm-up [34]. Similarly, although effects dissipated after six minutes, Chen et al. [35] has reported improvements in countermovement jump height following multiple sets of depth jumps. Turner et al [33] have recently reported that ~75 s of alternate-leg bounding performed with (+10% body mass) and without (body mass only) a weighted vest, potentiated subsequent sprint performance when compared to a control trial. Notably, a greater enhancement of sprint performance was observed in the body mass plus 10% trial when compared to the body mass only trial and this increase was related to the baseline speed of the participants.

Practitioners may therefore wish to recommend plyometric activities during the final stages of half-time to enhance subsequent performance, possibly as part of the half-time rewarm-up. However, as mentioned previously, consideration should be given to the fact that a transient reduction in performance is commonly observed in the immediate period (i.e., <3 min) following the preload stimulus [30] and that the effects of PAP as a specific half-time strategy have not been directly examined.

2.3 The use of videos and feedback (hormonal priming)

Half-time often includes a period of tactical instruction, be it either individual or team-based, which may utilise video playback (Figure 1) [1]. A number of authors have reported that the content of videos watched prior to exercise can influence subsequent physical performance. For example, in professional rugby players, Cook and Crewther [36] observed improvements in squat strength 15-min after watching short (4 min) video clips which included aggressive, training, erotic or humorous content. Notably, the aggressive video caused significant increases in salivary testosterone that exceeded all other video types and improved squat performance more so than either the erotic or humorous clips. Moreover, viewing footage 75 min before a match which showed successful skill executions performed by an athlete which was reinforced with positive coach feedback promoted the highest pre-game testosterone concentrations and best subsequent performance ratings [37]. Conversely, presenting footage of successful skill executions of opposing players while providing cautionary coach feedback, induced an enhanced stress response [37].

While the direct effect of strategies that seek to increase testosterone concentrations during the half-time break have not been examined, and assuming that the relationships between pre-match testosterone concentrations and match performance [38] remain true, it is plausible that strategies which elevate free testosterone employed during the half-time break may improve subsequent match performance. As video footage and player/coach interactions are commonly used during current half-time practices, modification of the footage and feedback presented to the players may offer a simple strategy to improve subsequent performance.

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2.4 Carbohydrate consumption

Team sports players are often encouraged to acutely consume carbohydrates on the day of competition in a manner that usually includes ingestion in the hours before exercise, throughout match-play and during breaks in play, such as at half-time [39]. The proposed mechanisms of ingesting carbohydrates relate to an effort to spare muscle glycogen and maintain blood glucose concentrations for the duration of a match [40-42]. However, the physiological response to carbohydrates consumed during exercise differs to that observed when carbohydrates are consumed in the non-exercising state [43].

The normal physiological response to ingesting carbohydrates that increase blood glucose concentrations in a non-exercising state is an up-regulation in the synthesis and secretion of insulin. Insulin, released from the beta cells of the islets of Langerhans, causes decreased lipolysis and increased glucose uptake in liver, skeletal muscle, and fat cells, in an attempt to normalize blood glucose concentrations [43]. Conversely, during high-intensity exercise, counter-regulatory hormones, including cortisol, growth hormone and catecholamines are stimulated and exert hyperglycemic responses [43]. Given the pattern of competitive match-play in team sports competition, it is surprising that the influence of carbohydrate supplementation on the glycaemic response to a bout of exercise that is completed after a period of recovery from a previous bout of exercise has received little attention.

Notably, ingesting sucrose in the form of a 6% carbohydrate-electrolyte beverage before (i.e., within two hours of commencing exercise and within five minutes of starting each half) and during (i.e., every 15 minutes of exercise) simulated soccer-specific exercise attenuated a decline in soccer shooting performance; specifically relating to the speed of the shots taken post-exercise [5]. However, in agreement with pilot data reported by Bangsbo et al. [44], the provision of exogenous carbohydrates prior to and during soccer-specific caused ~30% reductions in blood glucose concentrations during the initial stages of the second half; a finding which has since been confirmed in both simulated and actual soccer match-play [4, 6]. This exercise-induced rebound glycaemic response is most likely explained by an increased glucose uptake by the previously active muscles, lowered catecholamine concentrations, and reduced stimulation of liver glycogenolysis can cause transient reductions in blood glucose concentrations at the onset of the second half [44].

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It has been proposed that cerebral glucose uptake begins to decline when blood glucose concentrations fall below 3.6 mmol·L^{-1} [45] and almost immediate reductions in cognitive performance occur when blood glucose concentrations fall below 3.4 mmol·L^{-1} [46-55]; concentrations which, although rare, are similar in magnitude to those previously reported in soccer players [56]. As changes in blood glucose concentrations have been found to influence the quality of cognitive and physical performances executed during and after soccer-specific exercise; strategies which maintain blood glucose concentrations for the full duration of a match may represent an opportunity to achieve maximum soccer performances. A number of factors; including, the glycaemic index of the carbohydrate consumed, timing of consumption and the dose consumed are likely to modulate the efficacy of carbohydrates consumed during the half-time break.

2.4.1 Glycaemic index

Commercially available sports drinks generally tend to consist of between 6 and 10% concentrations of high-glycaemic index carbohydrates (e.g., Maltodextrin). Ingesting high-glycaemic index carbohydrates while in a non-exercising state, such as that observed during the initial phases of half-time, results in rapid increases in postprandial blood glucose concentrations. However, consumption of high-glycaemic index carbohydrates in the hour before exercise has also been reported to lower blood glucose concentrations 15-30 min after starting exercise [47, 57]; a response attributed to free fatty acid inhibition which increases carbohydrate usage throughout isolated exercise bouts performed soon after carbohydrate ingestion [47].

As highlighted above, we have consistently reported that consuming sucrose-electrolyte beverages before, and throughout, simulated soccer match-play caused transient reductions in blood glucose concentrations in the initial stages of the second half of soccer-specific exercise [5, 6, 58]. However, low glycaemic index carbohydrates prolong the delivery of glucose to the systemic circulation. Indeed, mean and peak oxidation rates of Isomaltulose, has been reported to be 50% and 42% lower than the oxidation rates of sucrose, respectively, when ingested at the same rate (1.1 g·min^{-1}) [59]. Although the effects of different glycaemic index carbohydrates consumed during the half-time period remains to be examined, it is plausible that a reduced rate of digestion and absorption of low-glycaemic index carbohydrates prolongs blood glucose concentrations that have typically been found to decline in the second half of intermittent activity.

2.4.2 Timing of ingestion

Consistent evidence provided from studies requiring that carbohydrates are consumed before a single bout of exercise demonstrate that the timing of pre-exercise carbohydrate ingestion can influence subsequent metabolic responses. For example, Moseley et al. [60] investigated the metabolic response to 75 g of glucose ingested 15, 45 or 75 min before exercise. Plasma glucose and insulin concentrations were significantly elevated immediately before exercise in the 15 min feeding group whereas the lowest insulin concentrations were observed when carbohydrate was ingested 75 min before exercise. Similarly, ingestion of a 20% fructose solution 15 min before the second half of an intermittent cycling protocol resulted in reductions in blood glucose concentrations compared to pre half-time values for 40 min of the second half [2]. Consequently, the timing of carbohydrate ingestion during the half-time period has the potential to influence responses; however, no studies have systematically examined the influence of modifying the timing of carbohydrates provided during half-time in soccer players.

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2.4.3 Dose consumed

In studies that have employed continuous exercise protocols and have focused on water absorption as a priority, the detrimental effects observed on gastric emptying and intestinal absorption have led to recommendations that beverages containing between 5 and 8% carbohydrates are consumed during exercise [59, 61, 62]. However, limited data currently exists about the effects of providing additional carbohydrates (>9% solutions) when intermittent, as opposed to continuous, exercise is performed; this is somewhat surprising given that ingestion of a 20% glucose solution has been reported to enhance sprint capacity after 90 min of intermittent cycling [2] and that a dose-dependent relationship exists between the amount of carbohydrate consumed and indices of cognitive function in non-exercising participants [63].

In recreational soccer players, greater blood glucose concentrations have been observed from 75 min onwards relative to a fluid-electrolyte placebo when a 9.6% carbohydrate-electrolyte beverage was consumed before and during (including at half-time) a simulated soccer match [4]. Interestingly, differences in glycaemic responses were observed despite similarities in blood glucose concentrations between conditions at 60 min (~4.0 mmol·L^{-1}). As the pre-exercise carbohydrate dosage appears to elicit similar glycaemic responses [59, 64], and that the rebound hypoglycaemic response appears to decay within the initial stages of exercise when high-glycaemic index carbohydrates are consumed [2, 60], it is plausible that provision of additional carbohydrates at half-time may afford ergogenic effects in the latter stages of a match; however, this remains to be confirmed.

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2.4.4 Interactions between carbohydrate ingestion and a half-time rewarm-up

It is well established that high-intensity exercise can elicit a hyperglycaemic response in both clinical and non-clinical populations. As pancreatic beta-cell activity is inhibited by an exercise-induced catecholamine release [65], carbohydrates provided during exercise can lead to elevated blood glucose concentrations. Therefore, it is plausible that a combination of high-intensity exercise performed during the half-time period and simultaneous carbohydrate ingestion could feasibly maintain blood glucose concentrations thereafter. In support of this, Brouns et al. [59] observed that ingestion of 600 ml of a concentrated Maltodextrin drink consumed during a 25 min cycle warm-up that included isolated sprint bouts, increased catecholamine concentrations, blunted the insulin response and actually increased blood glucose concentrations at the onset of exercise. Although reductions in blood glucose concentrations were observed after 20 min of subsequent continuous exercise, these differences were non-significant. Consequently, a half-time rewarm-up that includes a high-intensity component, combined with the ingestion of carbohydrates, may prove beneficial for team sports players who experience an exercise-induced rebound glycaemic response. However, this is yet to be determined when carbohydrates are provided during recovery from previous activity and when the exercise performed is intermittent in nature.

2.4.5 Carbohydrate mouth rinsing

Swilling carbohydrate solutions around the mouth before expectoration can positively influence the perception of effort during subsequent exercise (for a review see Rollo and Williams [66]) and facilitate peak power output during the initial stages of repeated sprint tests [67]. Such responses have been attributed to the excitation of reward and motor control centres in the brain [68] and an increased excitability of the corticomotor pathways [69] via oral receptor stimulation. Although it remains to be determined whether the presence of carbohydrate in the mouth can facilitate improvements in subsequent performance when used as a half-time strategy, the benefits of mouth swilling observed during exercise provide a rationale for using this strategy on the day of a match.

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2.5 Caffeine consumption

The beneficial effects of caffeine, a central nervous system stimulant, for team-sport athletes have been proposed to relate to the attenuation of fatigue-related decrements in skilled performances, concentration or cognitive function as opposed to enhanced endurance capacity [70]. With respect to soccer skill performance, the efficacy of caffeine is unclear [71] despite the mean sprinting performances of recreational players being improved when doses of 6 $mg \cdot kg^{-1}$ BW was co-ingested with 142 ± 3 $g \cdot h^{-1}$ of carbohydrate [4]. Additionally, the mean performance of rugby passes made over the duration of a simulated match was improved when caffeine was ingested [72]. Therefore, caffeine consumed during half-time may be efficacious for subsequent performance.

The time-course of peak systemic concentrations of caffeine and it's metabolites following acute ingestion is likely to be of interest to practitioners considering whether to use this nutritional ergogenic aid during half-time. The consumption of caffeine in either the fed or fasted state appears to influence the appearance of caffeine in the circulation [62]; nevertheless, when the mechanisms of action are reliant upon absorption via the lower gastrointestinal tract, peak concentrations of caffeine and/or its metabolites are generally realised within one and three hours of ingestion. However, the efficacy of drug administration has been proposed to be related to its speed of absorption [73] and the ergogenic effects of caffeine have also been attributed to the antagonism of receptors in the upper gastrointestinal tract facilitating a central modulation of motor unit activity and adenosine receptor stimulation [74].

In the last decade, caffeinated chewing gums have become commercially available and have been associated with significantly faster absorption times when compared to a traditional pill-based administration modality [75]. For example, Ryan et al. [73] have recently observed improved cycling performance when caffeinated gum containing 300 mg of caffeine was provided five minutes before exercise. Interestingly, providing the same dose of caffeinated gum 60 and 120 minutes prior to the start of exercise negated the ergogenic effects observed. Despite very few studies having investigated the effects of this novel method of caffeine delivery, early evidence suggests that caffeinated gum may benefit the performance of intermittent team sports players. Furthermore, the time-course of effects of action of caffeinated gums mean that they could plausibly be consumed during half-time or during the match itself.

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3.0 Model of theoretical application

As reviewed, the transition from a period of exercise to rest and back to exercise replicates the general demands of a number of team sports. This pattern of activity induces a number of physiological effects which appears to influence performance during subsequent exercise. Notably, impaired performance has been observed during the initial stages of the second half. Therefore, when seeking to optimize performance throughout the full duration of competition, half-time is an opportunity to employ specific strategies that seek to maintain performance throughout the second half.

However, the match-day practices of professional teams are often very structured and rigid in nature. It is therefore important that any proposed modification to the half-time period seeks to complement, rather than replace, existing protocols. Therefore, practical guidelines on how to incorporate such strategies may be beneficial for the Sports Scientist and/or Strength and Conditioning coach. A theoretical model of organizing the half-time period to incorporate both the practices currently employed and the strategies we propose to acutely enhance performance is outlined in Figure 2 and is based on an assumed 15 min break in play.

***** INSERT FIGURE 2 NEAR HERE *****

In order to attenuate the losses in body temperature observed during the half-time break, strategies that seek to maintain body temperature, and thus temperature-mediated pathways [7], should be considered. Heated clothing, outdoor survival jackets, and heating pads can be applied with relatively little inconvenience to athletes, and have proved beneficial when seeking to attenuate reductions in performance attributable to T_m loss [7, 9, 26]. Furthermore, an increased changing room temperature may also prove worthwhile.

At some point throughout half-time, individualized footage of successful player executions supported by affirmative positive cues from a coach may also benefit a player's subsequent performance [37]. However, it should be noted that if such videos focus upon the successful skill executions of opposing players while cautionary coach feedback is provided, an enhanced stress response can be observed [37].

Active rewarm-ups administered in the final stages of half-time improve subsequent physical and technical performance by attenuation of the reductions in body temperature seen when passive half-time practices are performed [8, 10, 11, 20]. As PAP has been observed following short duration plyometric activities [33], such exercises, when used as part of a rewarm-up strategy, may serve as a time-efficient method of improving subsequent performance.

Due to the mechanisms of action, the presence of caffeine and carbohydrate in the mouth has been found to facilitate motor output and improve subsequent exercise [67, 73]. However, based upon literature examining the efficacy of caffeine, if the duration between ingestion and subsequent exercise is prolonged, the ergogenic effects of these substances can be lost [73]. Therefore, within the final stages preceding the restart of competition, the provision of caffeinated gum and carbohydrate solutions (for the purposes of mouth swilling) should be considered (Figure two).

Finally, when seeking to minimize perturbations in blood glucose concentrations that have consistently been observed when recommencing the second half of exercise, it is plausible that half-time strategies relating to the consumption of exogenous energy (i.e., carbohydrates) could be optimized by modifying the glycaemic index of the beverage consumed, the timing of ingestion, the amount of carbohydrate consumed and/or by combining ingestion with a half-time rewarm-up. Therefore, consideration of these factors should be given; especially in players deemed to be susceptible to reduced blood glucose concentrations upon restarting exercise.

4.0 Summary

Periods of reduced activity between successive exercise bouts have been found to influence an array of physiological responses. Furthermore, reduced physical and cognitive performance, as well as increased risk of injury, has been identified in the initial stages of the second half of team-sport competition. Therefore, the support of previous authors for the use of heat maintenance strategies, half-time rewarm-ups (including actions to induce post-activation potentiation), hormonal priming (through the use of videos) and caffeine and carbohydrate consumption, means that a method which combines a number of these strategies for use on the day of competition may be of interest to Sports Scientists and Strength and Conditioning coaches involved with team sports. In addition to appraising the evidence of these isolated strategies, we have presented a practical model that allows combination of a number of interventions that could theoretically elicit additive effects over the use of such strategies alone. However, given the differences that exist between sports in half-time regulations (e.g., duration of break, access to pitch etc.), and a player’s normal practice, we recommend that the model is interpreted with considerable flexibility and we acknowledge that some adjustment is likely dependent upon the player’s involved.

5.0 REFERENCES

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Figure legends

Figure 1: Current model of strategies employed during a typical 15 min half-time period

Figure 2: Theoretical model of strategies suggested during a 15 min half-time period