A continuous mental task decreases the physiological response to soccer-specific intermittent exercise

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ORIGINAL ARTICLE

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Background: Epidemiological findings of higher injury incidence during the latter stages of soccer match-play have been attributed to fatigue.
Objective: To examine the interaction of physical and cognitive responses during soccer-specific intermittent exercise.
Method: Ten semi-professional soccer players completed a 90-minute laboratory-based treadmill protocol replicating the activity profile of soccer match-play. Two separate trials were performed in randomised order, with and without the added stressor of a continuous grid-based vigilance task. The exercise task comprised six repetitions of a 15 minute activity profile, separated by a passive 15 minute half-time interval. The vigilance task required continual attention and sporadic target response within a letter grid. Physical response (RPE, heart rate, blood lactate, salivary cortisol) and cognitive performance (response time, response accuracy) were quantified at 15 minute intervals.
Results: Completing the exercise task with the vigilance task resulted in decreased physiological (heart rate, blood lactate) response. This may be attributed to externally directed attention, resulting in association with the cognitive task and subsequent dissociation from the physical effort. Response speed generally improved with exercise duration, while there was evidence of impaired accuracy in the early stages of the first half and the latter stages of the second half.
Conclusion: The interaction of physical and mental work was not additive in nature. The mental task had a masking effect on the physical response. Performing physical exercise tasks without due regard for appropriate psychological stimuli may therefore overestimate the physiological response.

Professional football is associated with an injury risk deemed unacceptable when evaluated against work-based criteria.[1] The increased incidence of injuries observed during the latter stages of match-play has been attributed to fatigue.[2] However, while previous studies[3–5] have attempted to replicate the physiological demands of match-play, much less consideration has been given to the psychological elements of fatigue.

The term ''fatigue'' exists within all cognate areas of sport and exercise science, but there is a lack of consistency in definition and no consensus as to what fatigue actually is. There is an implicit assumption that there is more than one type of fatigue, with distinctions made in the literature between many types of fatigue including physical, mental, emotional and sleep-related.[6] However, the relationship between fatigue types and their cumulative influence has received little attention. Competitive soccer match-play is likely to impose simultaneous demands of more than one type of fatigue.

Notational analyses[7 8] have provided data upon which to base a physical work-rate profile of match-play. However, less is known regarding the psychological parameters of football. Intuitively, it would seem that the cognitive profile is also characterised by a self-paced intermittent activity profile, periods of high intensity decision making and concentration interspersed with low activity. While attention must be maintained throughout the game, the need for decision making will be sporadic dependent upon the context of the match situation.

A large body of research has addressed the effects that physical exertion has on the performance of cognitive tasks.[9] Increased speed of response on soccer-specific tasks by experienced soccer players has been observed during moderate and maximal intensity exercise.[10–12] However, the cycle ergometry exercise modality fails to validly represent the physical demands associated with soccer match-play. In contrast, little research has focused on the influence that carrying out cognitive tasks can have on physical exertion. The aim of the present study was to examine the cumulative effect of completing a continuous vigilance task on the physiological responses to soccer-specific intermittent activity.

METHODOLOGY

Subjects

Ten male semi-professional football players (Mean ± SD; age 24.7 ± 4.4 years, body mass 77.1 ± 8.3 kg, VO_{2max} 63.0 ± 4.8 ml·kg·min^{-1}) were recruited. All were regular first team starters and free from injury over the previous season. Given the nature of the psychological task, selection criteria also included no reported literacy disorders. All players completed, on average, two squad training sessions and one match per week. All participants provided written informed consent in accordance with departmental and university ethical procedures.

Experimental design

Participants were tested between 15:00 and 17:00 or between 16:00 and 18:00 in accordance with regular competition and training times to account for the effects of circadian variation.[13] Participants attended the laboratory in a 3-hour post-absorptive state, having performed no vigorous exercise or consumed any alcohol or caffeine in the 24 hours prior to testing, and with diet standardised for 48 hours preceding each test. Players

Abbreviations: BLa, Blood lactate; HR, heart rate; INT, intermittent protocol; PSY, psychological protocol with added vigilance task; RPE, ratings of perceived exertion

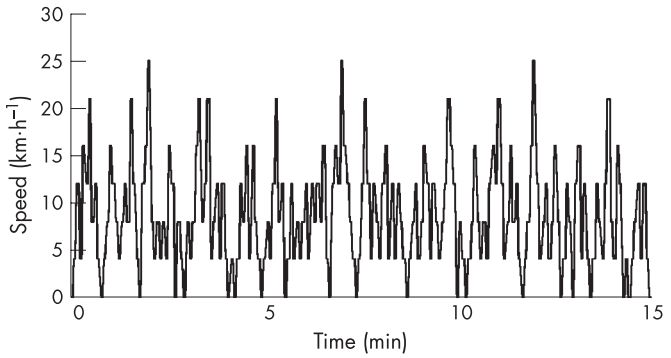

Figure 1 Schematic representation of the soccer-specific intermittent protocol.

consumed 500 ml water 2 hours prior to testing to ensure euhydration. The participants attended the laboratory on two separate occasions at the end of the competitive playing season. During this period the training load of the playing season was replicated by conducting squad training sessions in addition to the testing sessions which replicated match-play.

Exercise task

Two exercise protocols were performed in a randomised order to account for accommodation effects. One trial comprised completion of a soccer-specific intermittent treadmill test,[3] designed to replicate the activity profile of professional soccer match-play.[8] In a separate trial the treadmill protocol was repeated while the player completed a continuous vigilance task. All familiarisation and testing sessions were performed on a programmable motorised treadmill (LOKO S55, Woodway GmbH, Steinackerstraße, Germany). Prior to completing both protocols each participant completed a standardised warm-up of 30 minutes replicating match-play preparation.

The soccer-specific intermittent protocol was based on notational analysis of professional match-play,[8] which categorised eight modes of activity based on the movement speed over 90 minutes of match-play. To provide a 15-minute activity profile the frequency of each mode of exercise was divided by 6 (table 1).

This dataset was arbitrarily distributed to provide a 15 minute activity profile replicating the activity pattern of professional football match-play (fig 1). The 15-minute activity profile resulted in a distance covered of 1.62 km, giving a total distance covered of 9.72 km. A constant treadmill incline of 2% was used to reflect the energetic cost of outdoor running at the speeds used in the protocol.[14]

Vigilance task

The computer-based vigilance task comprised a grid of randomly distributed letters (fig 2). This grid was modified in layout for each 15 minute exercise period so as to minimise a learning effect, although the number of target response squares did not vary. At 1 Hz frequency a grid square was randomly highlighted. At each instant that a grid square containing the letter b was highlighted the player was required to press a handheld trigger. This trigger was selected so as to minimise alteration to the running style, with no requirement to be pointed at the screen. The vigilance task comprised a total of 90 target responses (b) and 810 non-target responses (d, p, q) for each 15 minute exercise period. The mean response speed for each correct response was calculated for each 15 minute period. Response accuracy was quantified as the number of errors made during each 15 minute period. An error was defined as failing to respond to the desired response or inappropriately selecting a non-desired response (d, p, q). The player was instructed that both speed and accuracy were to be measured.

Familiarisation with the task was facilitated during the treadmill familiarisation sessions prior to testing. The vigilance task was completed both at rest and during treadmill exercise for the purpose of habituation. Modifications were made to both the vigilance task and the activity profile with respect to the trial conditions.

Table 1 Movement activities replicated in the intermittent treadmill protocol

Activity	Number of activities	Mean duration (s)
Standing (0 km·h^{-1})	20	7.8
Walking (4 km·h^{-1})	55	6.7
Jogging (8 km·h^{-1})	42	3.5
Low speed (12 km·h^{-1})	46	3.5
Moderate speed (16 km·h^{-1})	20	2.5
High speed (21 km·h^{-1})	56	2.1
Sprint (25 km·h^{-1})	3	2.0

Nude body mass

Dry nude body mass was measured before and after exercise.

Perceived exertion

Subjective ratings of perceived exertion were recorded using a 6–20-point scale[15] at the midpoint of each 15 minute period.

Heart rate

Heart rate was monitored continuously at 5 second intervals using short-range radio telemetry (Polar Team System, Polar Electro, Kempele, Finland). Mean heart rate was calculated for each 15 minute exercise period during both protocols and during the passive 15 minute half-time interval.

Blood lactate

Blood lactate concentration was determined at rest and at the end of each 15 minute exercise period, including the end of the half-time interval. The Lactate Pro blood lactate test meter (ARKRAY, Japan) was first calibrated according to the manufacturer's guidelines. The puncture site on the fingertip was cleaned using an alcohol pad and dried with a sterile pad, and subsequently a sample of free-flowing blood was collected using a Lactate Pro test strip as directed by the manufacturer.

Salivary cortisol

Salivary cortisol concentrations were determined at 15 minute intervals throughout the duration of each trial. To obtain the

p	b	d	q	q	b
p	b	q	d	d	d
b	d	q	d	p	p
q	b	q	p	p	b

Figure 2 An example of the vigilance task response grid.

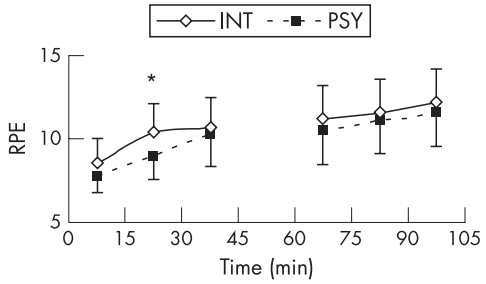

Figure 3 Mean (±SD) subjective rating of perceived exertion (RPE) during the soccer-specific intermittent (INT) protocol and with the added vigilance task (PSY).

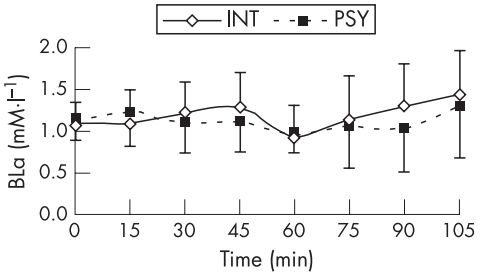

Figure 5 Mean (±SD) blood lactate concentration (BLa) during the soccer-specific intermittent (INT) protocol and with the added vigilance task (PSY).

saliva sample participants were required to chew on a plain cotton salivette for 45 seconds. During exercise the salivette was administered during a stationary phase.

All saliva samples were frozen at −80℃ prior to assay. The thawed sample was then vortexed and centrifuged at 3000 rpm for 15 minutes. The salivary cortisol enzyme immunoassay (Salimetrics, USA) was carried out according to manufacturer's instructions. Clear 25 µl samples were pipetted in duplicate into pre-labelled wells of the high-sensitivity enzyme immunoassay plate for which the coefficient of variation was <7%. Absorbance readings were measured at 450 nm (Biotek Synergy HT-R, Biotek Instruments, Vermont, USA). The plate also comprised duplicate standards (25 µl) of known concentrations from the kit manufacturer (Salimetrics, USA) which were used to plot a 6-point standard curve (0.19–49.66 nmol l^{-1}) for each plate using a 4-parameter sigmoid minus curve fit. The percentage bound for each standard and unknown was calculated and plotted against the log of the concentration for each standard, and the concentration of each sample determined by interpolation.

Statistical analysis

A two-way (treatment x time) analysis of variance (ANOVA) was performed to compare differences in each of the measures between the two exercise conditions, and over the duration of each trial. Significant differences between means were identified using a least-squares difference post-hoc test. Significance was accepted at $p \leqslant 0.05$, all results being reported as the mean ± standard deviation of the mean.

RESULTS

The soccer-specific intermittent protocol (INT) was completed in laboratory conditions of 21.1±1.4℃ and 49±3% relative humidity. The same protocol with the added psychological stress induced by completion of the vigilance task (PSY) was completed in similar conditions of 20.9±0.6℃ and 53±6% relative humidity. Reductions in body mass were observed in both trials (INT = 1.2±0.3 kg; PSY = 1.1±0.1 kg) but were not significantly different.

In the following presentation a significant difference ($p \leqslant 0.05$) between trials is denoted by an * at each time point during the exercise protocol.

Rating of perceived exertion

Subjective ratings of perceived exertion (RPE) were greater during the INT protocol than during the PSY protocol throughout (fig 3). This difference was statistically significant only over the second 15 minutes of the first half ($RPE_{15–30}$: INT = 10±2, PSY = 9±1). ANOVA revealed a significant main effect for time during both protocols, with RPE gradually increasing throughout the duration of each trial.

Heart rate

Heart rate (HR) was greater during the INT protocol than during the PSY protocol for each of the 15 minute activity periods (fig 4). This difference was significant ($p<0.05$) until the final 15 minute period. The ANOVA revealed a significant main effect for exercise time during the INT protocol, but not during the PSY protocol.

Blood lactate

Blood lactate concentration (BLa) was equal for both the INT and PSY trials at rest ($INT_0 = 1.1 \pm 0.3$ mM·l^{-1}; $PSY_0 = 1.1 \pm 0.2$ mM·l^{-1}) and at the end of the 15 minute half-time interval ($INT_{60} = 0.9 \pm 0.3$ mM·l^{-1}; $PSY_{60} = 1.0 \pm 0.2$ mM·l^{-1}). Apart from the end of the first 15 minute period, BLa tended to be greater during the INT protocol than during the PSY protocol (fig 5), but at no time was this difference significant. ANOVA revealed no significant main effect for time during either protocol.

Salivary cortisol

A correlation coefficient of $r^2 \geqslant 0.98$ was obtained for each standard curve used to determine salivary cortisol concentra-

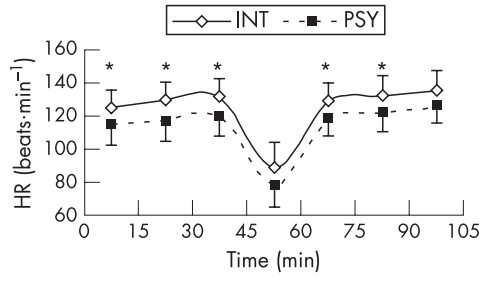

Figure 4 Mean (±SD) heart rate (HR) response during the soccer-specific intermittent (INT) protocol and with the added vigilance task (PSY).

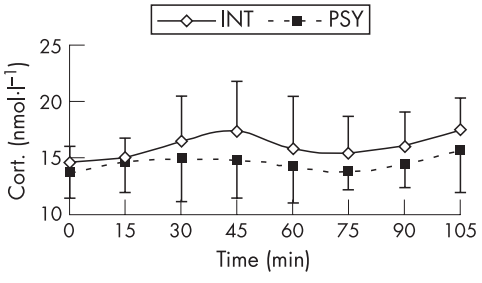

Figure 6 Mean (±SD) salivary cortisol concentration (Cort.) during the soccer-specific intermittent (INT) protocol and with the added vigilance task (PSY).

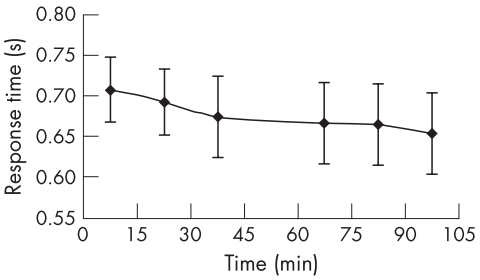

Figure 7 Mean (±SD) response time during the vigilance task.

tions. Salivary cortisol concentration appeared greater during the INT protocol than during the PSY protocol at the end of each exercise period (fig 6). However, ANOVA revealed no significant main effect for trial. No significant main effect for time was observed for either protocol, despite the trend for a progressive increase during each half.

Response time

Response time during the vigilance task improved as a function of exercise duration throughout the PSY protocol (fig 7). ANOVA revealed a significant main effect for exercise duration, with mean response time during the final 15 minutes (0.65±0.05 seconds) significantly faster than during the first 15 minutes (0.71±0.04 seconds).

Response accuracy

Performance of the vigilance task was also quantified as the numbers of errors made in response (fig 8). ANOVA revealed a significant main effect for exercise duration. There was a significant reduction in errors made during the first 30 minutes of the first half and a significant increase in errors made during the final 30 minutes of the second half.

DISCUSSION

In the present study the exercise "model" was validated in terms of its structure (or input) being a direct representation of the activity profile of match-play.[8] The physiological response to the intermittent protocol was lower than observed in competition.[8 16] This may be attributed, in part, to the modality of exercise. The treadmill does not allow replication of the "unorthodox" modes of backward and lateral movement[17 18] or the "utility" movements such as dribbling with the ball[19] and fails to represent the emotional stress associated with match-play.[20] Based on such restrictions it could be argued that a laboratory-based replication of match-play activity profile should not elicit the same response as competition.

The primary aim of the study was to investigate the interaction of physical and mental stress during soccer-specific intermittent exercise. There was very little difference recorded in the rating of perceived exertion between the trials. However, the inclusion of the vigilance task, imposed as an additional stressor on the intermittent activity task, reduced the physiological response.

Cognitive strategies used during exercise have been conceptualised along the attentional foci of direction. An associative (internal) focus of attention would process task-oriented information such as muscular fatigue or increased heart rate.[21] A dissociative (external) attentional focus or distraction diverts attention away from self-awareness and towards external stimuli.[22] Exercisers using dissociative strategies have reported

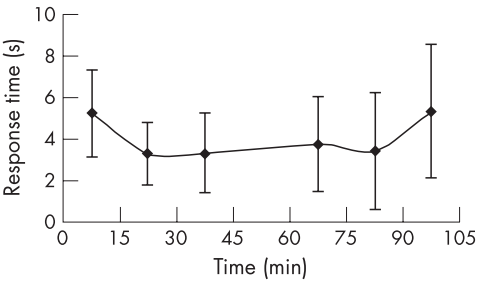

Figure 8 Mean (±SD) number of errors made during the vigilance task.

What is already known on this topic?

Football is characterised by an intermittent and irregular activity profile. The high incidence of injuries incurred and goals conceded during the latter stages of match-play have been attributed to fatigue.

The physiology of intermittent exercise has been well considered, but in contrast little is known regarding the psychological components of fatigue in football, or indeed the interaction of physiological and psychological fatigue.

- A large body of research has addressed the effects that physical exertion has on the performance of cognitive tasks.
- Decision-making speed has been observed to increase during both moderate and maximal intensity exercise in experienced soccer players.
- However, the exercise modality has typically failed to represent the activity profile of soccer, and little is known regarding the influence of carrying out cognitive tasks on physical exertion.

What this study adds?

- This study uses a running protocol that reflects the intermittent nature of soccer match-play.
- Response time improved as a function of exercise duration in each half of the simulated game.
- Response accuracy improved during the first 30 minutes of the first half, but failed to improve further over the final 15 minutes of the first half, and deteriorated during the final 30 minutes of the second half.
- This increased frequency of errors with no reduction in response time might predispose the player to increased risk of injury. In both response time and accuracy there was also evidence of performance impairment following the passive half-time interval.
- While there was evidence of interaction between physical and mental stressors, this interaction was not additive in nature. There was very little difference recorded in the rating of perceived exertion, however, the inclusion of the vigilance task reduced the physiological response. Completion of the vigilance task resulted in decreased physiological response to the intermittent protocol, attributed to association with the vigilance task and subsequent dissociation from the exercise task.
- Failing to consider the psychological stimulus presented during exertion may therefore overestimate the physiological demands.

reduced perceived exertion and improved endurance and/or speed.[23] By incorporating a cognitive task into the soccer-specific treadmill protocol, participants' attention may have become focused externally, and through involvement with the task they might have become dissociated from the physical sensations of effort.

It has been suggested that the exercise environment can significantly influence the direction of attention.[24] Environments lacking information, such as laboratories, direct individuals to encode more internal information and report more fatigue. More stimulating environments, such as match-play, may reduce the attention directed to internal sensations. So, for true replication of the physical demands of soccer on players, the psychological environment in which exertion takes place should be considered. Without considering psychological stimulus during exertion, previous studies may be overestimating the physiological demands.

A secondary aim of the present study was to examine the influence of exercise duration on performance of the vigilance task. The exercise task was not designed to induce a state of physical fatigue, but rather to simulate the physical workload of soccer match-play. Response time improved as a function of exercise duration in each half, with performance in the second half better than the first half. The exercise task appears to "energise" the subject, but not beyond optimal arousal with respect to the inverted-U relationship between arousal and cognitive performance.[25] Such an explanation is also in line with the suggestion that exercise produces changes in state processes that are responsible for the allocation of attentional resources.[9] Certainly the exercise intervention is not maximal, and being soccer-specific comprises long periods of low-intensity activity.

Performance of the vigilance task was also quantified in the numbers of errors made in response. Response accuracy improved significantly during the first 30 minutes of the first half. The possibility that this might be attributed to a learning effect is negated by the familiarisation trials performed by all participants. Response accuracy failed to improve further over the final 15 minutes of the first half, and deteriorated during the final 30 minutes of the second half. The impaired accuracy in response during the latter stages of each half may be a factor in the higher incidence of injuries observed during the latter stages of match-play.[2] Motor system efficiency is compromised in the presence of both physical and cognitive stress,[26] with motor control errors increasing in frequency when two or more systems are simultaneously fatigued.[27] The mechanisms of injury are typically considered as physical factors, however, a lack of awareness and attention have also been attributed to injury incidence.[28 29] No reduction in response time despite the increase in errors of judgement is indicative of increased risk in response,[30] and this aspect of mental performance might predispose the player to increased risk of injury.

In both response time and accuracy there was evidence of performance impairment following the passive half-time interval. The potential impairment of mental performance after the half-time interval supports epidemiological observations of a relatively high risk of injury in the initial stages of each half.[31] Half-time strategies might be developed that consider both mental and physical preparation for the second half.

CONCLUSIONS

There was evidence of interaction between physical and mental stressors. However, this interaction was not additive in nature. Completion of the vigilance task resulted in decreased physiological response to the intermittent protocol, attributed to association with the vigilance task and subsequent dissociation from the exercise task.

While response time decreased as a function of exercise duration, suggesting quicker response, the number of errors made increased. The latter stages of match-play are therefore characterised by greater inaccuracy in response, and perhaps greater risk. Cognitive response was slower during the initial stages of each half, suggesting that warm-up and half-time strategies be considered to account for both physiological and psychological readiness.

Research has made great progress in replicating and monitoring the physical demands of soccer. Future research should consider simulating the psychological and physical environment in which soccer exertion takes place, and observing the associated physiological and psychological responses.

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