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Selected Physiological, Perceptual, and Physical Performance Changes During Two Bouts of Prolonged High-Intensity Intermittent Running Separated by 72 Hours

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Abstract

Dobbin, N, Lamb, KL, and Twist, C. Selected physiological, perceptual, and physical performance changes during two bouts of prolonged high-intensity intermittent running separated by 72 hours. *J Strength Cond Res* 31(12): 3474–3481, 2017—This study investigated the effects of performing a second 90-minute intermittent running protocol 72 hours after an initial trial on selected physiological, perceptual, and sprint running measures. Eight subelite soccer players provided measures of isokinetic muscle function, countermovement jump (CMJ), 10-m sprinting, and muscle soreness before, and at 0, 24, 48, and 72 hours after a 90-minute intermittent high-intensity running bout (IHIR-1). A second 90-minute IHIR bout (IHIR-2) was performed 72 hours after the first. Heart rates, ratings of perceived exertion (RPE), blood lactate concentration [Bla], and 10-m sprint times were recorded periodically during both IHIR. Analysis of effects revealed that in the 72-hour period after IHIR-1, there were *most likely* increases in muscle soreness and *likely to very likely* deteriorations in CMJ, 10-m sprint, and isokinetic muscle function. During IHIR-2, heart rates (*possibly* to *likely*) and [Bla] (*possibly* to *very likely*) were lower than IHIR-1, whereas RPE remained unchanged. Sprint times during IHIR-2 were also *likely* to *very likely* higher than in IHIR-1. It was evident that these team sport players exposed to repeat bouts of prolonged high-intensity running within 72 hours downregulated their sprint performan-ces in the second bout despite no change in perceived effort. These findings have implications for managing training and match loads during periods of intense scheduling.

Key Words team sports, repeat efforts, exercise-induced muscle damage, pacing

Introduction

The importance of recovery from strenuous exercise has become a topical area of interest in applied sport science research, particularly with respect to team sports and the likelihood of tissue damage that occurs from an increase in intensity or duration of competition or training demands (6,23,29). In addition, the metabolic stresses associated with prolonged high intensity intermittent nature of team sports (21,36) have a role to play in the symptoms of exercise-induced muscle damage (EIMD) (29). Symptoms of EIMD include an inflammatory response (14,38), increased stiffness, soreness, muscle swell-ing (9,13), and elevations in blood proteins such as creatine kinase (15). More importantly, detrimental effects of tissue damage on jumping (26,30,32), sprinting (18,30), and agility performances (18) are practically meaningful for team sport athletes who regularly perform high-intensity intermittent exercise as part of training and matches. Markers of EIMD have been documented both after soccer matches and "sim-ulations" designed to replicate them (2,23,24,30,37) and re-ported to peak at around 24–48 hours (24,31) and endure for up to 72 hours postexercise (23,24,37). Ascensão et al. (2) and Fatouros et al. (14) reported that performances of verti-cal jumping, sprinting, and knee extensor strength were typ-ically 5–15% lower in professional soccer players after a soccer match. Indeed, because soccer players of all stand-ards are often required to perform in successive matches or training sessions with only 2 or 3 days of recovery (7), EIMD might impact negatively on any subsequent running ability.

Interestingly, several studies using time-motion analysis have reported no differences in running characteristics and technical performance during congested fixture periods in soccer players (1,10,11), although more matches were lost and injury rate was higher when these shorter between-match periods occurred (4,10). However, the sensitivity of motion analysis methods to detect fatigue-related declines in performance and/or the role of pacing during a match has been questioned (7). Moreover, natural variations in events between matches owing to several contextual factors make it difficult to interpret the causes of differences in running

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demands between matches (7,8), particularly with respect to high-intensity running (19.8–25.2 km$h[21]) and sprinting (.25.2 km$h[21]) which can vary by up to 16% and 30%, respectively (17). Accordingly, the use of intermittent high-intensity running simulation protocols using controlled speeds (e.g., 31) provide a suitable model to understand bet-ter the effects of prolonged fatigue on an individual's move-ment characteristics.

Of the limited data that exists, Rollo et al. (35) reported that playing 2 soccer matches per week over a 6-week period resulted in significant reductions in counter-movement jump (CMJ), 10- and 20-m sprint, and Yo-Yo intermittent recovery test performances. Although they speculated that playing multiple matches per week had a negative impact on muscle function, possibly due to repeated skeletal muscle fiber dam-age, the authors were unable to quantify how this impacted on aspects of match performance (from one match to the next). Indeed, no studies have examined how a second match occurring soon after an initial match has been affected in terms of its physiological or perceptual demands (internal load). Understanding how indirect markers of EIMD (e.g., force loss, muscle soreness) accumulated from prolonged exercise impact on physical performances during subsequent iterations of the same type would inform athlete manage-ment protocols around periods where both training and competition volumes are high. Therefore, the purpose of the present study was to examine the impact of an initial prolonged high intensity running bout (team sport simula-tion protocol) on measures of running performance and internal load demonstrated in a subsequent repeat bout pre-sented only 72 hours later.

METHODS

Experimental Approach to the Problem

The study used a repeated measures design, with partic-ipants attending the laboratory on 5 occasions. All participants were required to refrain from strenuous exercise in the 2 days before the initial visit and during the 4 subsequent visits, to maintain a normal diet through-out and to abstain from using analgesic agents or recovery strategies during the testing period. Participants completed a multistage shuttle run (34) followed by familiarization to the intermittent high-intensity running (IHIR) protocol and the measures of muscle function. Participants com-pleted 2 IHIR bouts (IHIR-1 and IHIR-2) 72 hours apart. During both IHIR trials, sprinting speed was measured for every sprint completed, heart rates were recorded throughout, and [Bla] and ratings of perceived exertion recorded immediately after each 15-minute block (i.e., dur-ing the 3-minute rest periods). Measurements of isokinetic muscle function, muscle soreness, CMJ height, and 10-m sprint performance were also recorded before and then immediately, 24, 48, and 72 hours after the IHIR-1. All measurements were performed at the same time of day (62 hours) to minimize the effect of any diurnal variation

and recorded in the same order as described for each visit. A period of ; 5 minutes was permitted between each measurement to reduce the effect of cumulative fatigue on subsequent performance.

Subjects

After institutional ethics approval, 8 male university soccer players (age 23 6 3 years, stature 176.8 6 5.7 cm, body mass 77.9 6 9.4 kg, predicted Vo2max 49.1 6 5.9 ml$kg[21]$min[21]) volunteered to participate in the study. All participants played in outfield positions, attended train-ing at least twice, and played 1 match per week over the previous 6 months. Subjects had no history of injury in the previous 6 months and were free of injury at the time of testing. After receiving verbal and a written explanation of the study, all participants provided written informed con-sent before taking part.
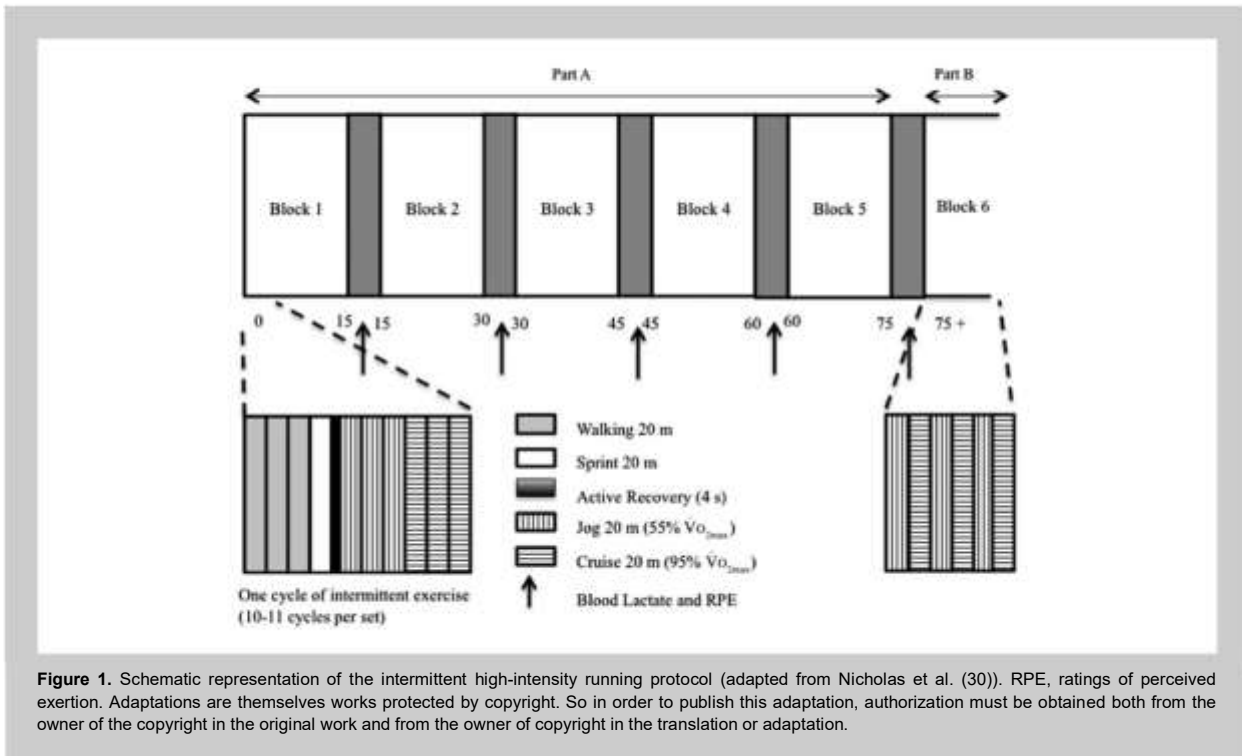
Procedures

The Multistage Shuttle Run Test. After a standardized warm-up, participants completed the multistage shuttle run test (MSSRT) in an indoor gymnasium (wooden surface). The test consisted of shuttle running between 2 markers set at 20 m, with the speed increasing every minute until exhaustion. The MSSRT score achieved was used to predict maximal oxygen uptake (Vo2max) and the speeds equivalent to 55 and 95% Vo2max for use during the IHIR (34).

Intermittent High-Intensity Running Protocol. To simulate the running demands of soccer, the Loughborough Intermittent Shuttle Test (31) was used for the IHIR. This required par-ticipants to alternate between walking, running, and sprint-ing over a distance of 20 m in an indoor gymnasium (wooden surface; 20 6 28 C, 38 6 2% relative humidity) for a period of 90 minutes. Briefly, participants completed 5 blocks that each lasted approximately 15 minutes with a 3-minute rest period between each (where water was con-sumed ad libitum). Each 15-minute block comprised a set pattern of intermittent high-intensity activity as follows (31):

- 3 3 20 m at walking pace
- 1 3 20 m at maximal sprint
- 4 seconds recovery
- 3 3 20 m at a running speed corresponding to 55% of individual Vo2max
- 3 3 20 m at a running speed corresponding to 95% of individual Vo2max.

In the sixth and final block, participants completed shuttle running that alternated every 20 m between speeds corre-sponding to 55 and 95% Vo2max until volitional exhaustion (Figure 1). Verbal encouragement was given by the same researcher before each sprint and during the time to exhaus-tion run to encourage a maximal effort. This protocol has been shown to closely replicate the movement demands of intermittent team sports with both sprints and running to exhaustion possessing acceptable reliability (31).
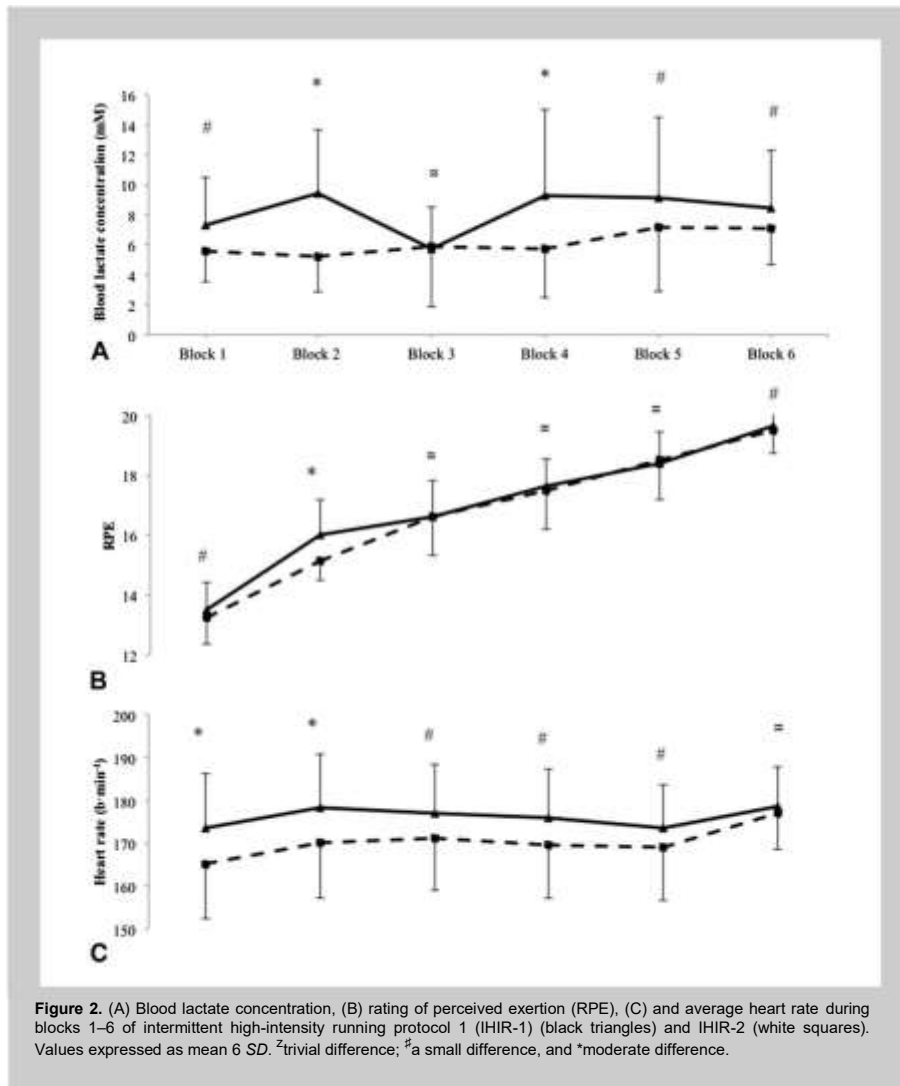
Figure 1. Schematic representation of the intermittent high-intensity running protocol (adapted from Nicholas et al. (30)). RPE, ratings of perceived exertion. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

Assessment of Isokinetic Muscle Strength. Peak knee extensor and flexor concentric strength were measured on the dominant limb using a isokinetic dynamometer (Biodex, multijoint System 3; Biodex Medical, New York, USA) at 608$s[21]. Before the test, a standardized 3-minute warm-up cycling at 50 W (Lode, Corival; Lode BV, Groningen, the Netherlands) was used. The participants were positioned in a seated position with the lateral femoral epicondyle aligned to the centre of the dynamometer axis of rotation. With the upper body secured, the lever arm was positioned at the distal point of the tibia and above the malleoli. The range

of motion (0–908) and limb mass were measured before testing to adjust for gravitational influences (18). Participants were given 2 warm-up trials before 5 maximal efforts, with visual and verbal encouragement being given throughout. Peak torque values were calculated by the dynamometer's software as the highest torque generated over the active range of motion for each action. In-house determined test-retest reliability coefficient of variation (CV) for the measurement peak isokinetic extension and flexion torques was 4.2–6.8% when measured over a range of 0 (full knee extension) to 908 (knee flexion).

TABLE 1. Changes in muscle soreness and function after intermittent high-intensity running protocol 1.*†

	Baseline	0 h	24 h	48 h	72 h
Perceived muscle soreness	0.3 6 0.6	3.6 6 2.0z	4.4 6 1.3z	4.4 6 1.8z	3.4 6 2.1§
CMJ height (cm)	42.9 6 2.8	40.5 6 3.7z	40.2 6 5.0z	41.2 6 5.9z	41.2 6 5.2§
10-m sprint (s)	1.55 6 0.05	1.64 6 0.1k	1.59 6 0.09z	1.59 6 0.08z	1.60 6 0.07z
Knee extensors peak torque (N$m)	238.7 6 32.4	217.1 6 30.7z	218.9 6 27.6§	227.7 6 29.0§	232.9 6 33.1
Knee flexors peak torque (N$m)	135.2 6 17.1	119.9 6 15.6§	120.9 6 9.9z	119.6 6 12.3z	122.7 6 10.1z

*CMJ = countermovement jump.
†Values are presented as mean 6 SD.
zDenotes moderate difference to baseline value.
§Denotes a small difference to baseline value.
kDenotes large difference to baseline value.

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Figure 2. (A) Blood lactate concentration, (B) rating of perceived exertion (RPE), (C) and average heart rate during blocks 1–6 of intermittent high-intensity running protocol 1 (IHIR-1) (black triangles) and IHIR-2 (white squares). Values expressed as mean 6 SD. ^{z}trivial difference; $^{\#}$a small difference, and *moderate difference.

correct technique was performed and the mean height of the 3 scores recorded for analysis. In-house determined test-retest reliability CV for the measurement of CMJ height was 2.0%.

Assessment of Perceived Muscle Soreness. Subjective measures of perceived muscle soreness were recorded while the sub-ject performed a squatting action using a 0–10 visual ana-log scale, where "0" equated to no soreness on movement and "10" meant their muscles were too sore to move. After dem-onstration of the appropriate technique and familiarization, subjects were instructed to per-form an unloaded squat to acti-vate the muscles of the lower limbs with their hands on their hips. Subjects flexed to a knee angle of approximately 908, at which point they were asked to indicate the degree of soreness on the visual analog scale. This has been shown to be a valid and reliable method for assess-ing the sensation of pain (33).

Assessment of Internal and External Load During the Intermittent High-Intensity Running Protocols. During each IHIR protocol, the heart rate was measured every 15 seconds using a recordable heart rate monitor (Polar Electro, S810i; Polar Electro, Oy, Finland; CV = 3.8%), the mean for each block being used in the analysis. Rating of perceived exertion (CV = 2.4%) was recorded using the Borg 6–20 scale (5) after participants were familiarized to the scale and how to use it using a set of standardized instructions (28). Blood lactate concentration ([Bla]; Arkray, Lactate Pro; Arkay, Kyoto, Japan; CV = 8.2%) was also measured from a fingertip capillary sample immediately after each block. Sprint times over 10 m (Brower, Speedtrap 2; Brower, Utah, USA) were recorded for each block of the IHIR, from which the mean value was later calculated to represent sprint performance.

Assessment of Sprint Performance. After a standardized warm-up, participants completed three 10-m maximal sprints with an initial 5-m acceleration area and a 2-minute active recovery between each. Speed was measured to the nearest 0.01 seconds using timing gates (Brower; Speedtrap 2, Brower, Utah, USA). In-house determined test-retest reliabil-ity CV for the measurement sprint performance was 1.1%.

Assessment of Countermovement Jump Performance. Two prac-tice jumps followed by 3 maximal jumps were performed using a jump mat (Just Jump System; Probotics, Inc., Alabama, USA). The participant was instructed to stand upright with hands on the hips, from which they flexed their knees to approximately 908, before extending into a jump. No arm swing was permitted, and participants were required to ensure that hands remained on hips throughout the jump. Each jump was observed by the researcher to ensure that the

Statistical Analyses

All dependent variables were log transformed to reduce bias due to nonuniformity of error that enabled our analysis using
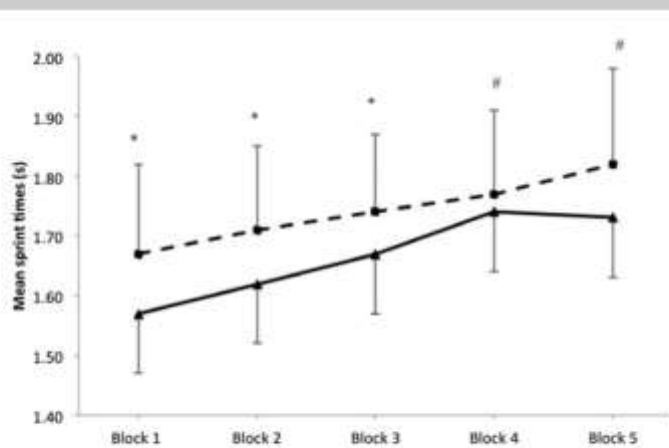
Figure 3. Mean sprint times (seconds) during blocks 1–5 of intermittent high-intensity running protocol 1 (IHIR-1) and IHIR-2. Trial 1 is denoted by solid line and trial 2 by dashed line. Values expressed as mean 6 SD. #a small difference; *moderate difference.

torque was very likely lower than baseline at 0 and 24 hours (29.1%, 0.62 6 0.27; and 27.8%, 0.53 6 0.30, respectively), likely lower at 48 hours (24.5%, 20.3 6 0.16), and possibly lower at 72 hours (22.5%, 0.16 6 0.18). Isokinetic knee flexor peak torque was likely lower than baseline at 0 hours (27.2%, 0.52 6 0.48) and very likely lower at 24–72 hours (210.3%, 20.75 6 0.50; 211.4%, 0.84 6 0.49; and 28.9%, 0.65 6 0.44, respectively).

Differences in Internal and External Load Between Intermittent High-Intensity Running Trials

the effect size (ES) statistic with 90% confidence intervals (CIs) and % change to determine the magnitude of effects. Magnitude-based inference statistics were used to provide information on the size of the differences, allowing a more practical and meaningful explanation of the data (3). The threshold for the magnitude of the observed change for each variable was determined as the within-participant SD in that variable 3 0.2, 0.6, and 1.2 for a small, moderate, and large effect, respectively (20). Threshold probabilities for a meaningful effect based on 90% CI were: ,0.5%, most unlikely; 0.5–5%, very unlikely; 5–25%, unlikely; 25–75%, possibly; 75–95%, likely; 95–99.5%, very likely; and .99.5%, most likely. Effects with 90% CI across a likely small positive or negative change were classified as unclear (20). All calcula-tions were completed using a predesigned spreadsheet (19) with data presented as mean 6 SD.

RESULTS

Muscle Function and Soreness Changes After Intermittent High-Intensity Running Protocol 1

There were most likely increases in perceived muscle sore-ness from baseline values after IHIR-1 (Table 1) at 0, 24, 48, and 72 hours (1,583%, ES 2.19 6 0.60; 2,152%, ES 2.42 6 0.61; 1,855%, ES 2.31 6 0.73; 1,500%, ES 2.16 6 1.01, respectively). There were very likely reductions in CMJ from baseline at 0 and 24 hours (25.9%, ES 20.81 6 0.59; and 26.8%, ES 20.94 6 0.60, respectively) with likely reductions at 48 and 72 hours (24.9%, 20.67 6 0.80 and 23.2%, 0.91 6 0.76, respectively). Sprint time over 10 m was very likely higher at 0 hours (5.7%, 1.61 6 1.36), likely higher at 72 hours (3.2%, 0.91 6 0.76) but unclear at 24 and 48 hours (2.6%, 0.74 6 1.08; and 2.7%, 0.76 6 1.20, respectively). Isokinetic knee extensor peak

Mean heart rates (Figure 2C) were likely lower in IHIR-2 than in IHIR-1 for block 1 (24.8%, ES 20.61 6 0.45), block 2 (24.6%, ES 20.60 6 0.41), block 4 (23.7%, ES 20.52 6 0.38), and block 5 (22.8%, ES 20.44 6 0.36), possibly lower for block 3 (22.5%, ES 20.29 6 0.26) but unclear for block 6 (20.8%, 20.15 6 0.60). [Bla] (Figure 2A) was likely lower during IHIR-2 at blocks 1 (221.2%, ES 20.44 6 0.54) and 4 (238.8%, ES 20.69 6 0.53), very likely lower at block 2 (243.9%, ES 20.75 6 0.51), possibly lower at block 5 (224.8%, ES 20.39 6 0.55), and unclear at block 3 (1.2%, 0.02 6 0.42) and block 6 (214.0%, 20.3 6 0.53). Ratings of perceived exertion (Figure 2B) was likely lower in IHIR-2 at block 2 (25.3%, 0.66 6 0.56) but unclear at all other time points. Time to exhaustion was possibly shorter (213.7%, 20.25 6 0.36) in block 6 of IHIR-2 (2.89 6 1.39 minutes) than in IHIR-1 (3.38 6 1.88 minutes).

Average 10-m sprint time (Figure 3) was very likely increased for block 1 and block 2 (6.2%, 1.09 6 0.55; and 4.9%, 0.78 6 0.53, respectively) and likely higher for block 3–5 (3.9%, 0.6 6 0.50; 3.3%, 0.47 6 0.32; and 4.9%, 0.41 6 0.36, respectively) during IHIR-2 compared with IHIR-1.

DISCUSSION

This study examined how EIMD caused by an intermittent high-intensity running protocol impacted on the physiolog-ical, perceptual, and physical responses to the same exercise performed 72 hours later. The initial high-intensity running bout (IHIR-1) caused moderate impairments of muscle function and large increases in soreness that persisted for up to 72 hours. When repeated 72 hours later, a down-regulation of sprinting performance, lower heart rate, and [Bla] during the second IHIR protocol (IHIR-2) was accompanied by an unchanged perception of effort.

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In the first IHIR, eccentric contractions from the numerous accelerations, decelerations, and changes in direction are likely to have provided the main stimulus for the symptoms of EIMD that followed. This is con-firmed by the observed reductions in isokinetic muscle function, sprint and jump performances, and elevations in muscle soreness that remained for 72 hours after the initial IHIR bout. These observations are consistent with previous studies reporting the time-course responses of impaired muscle function and muscle soreness after the same prolonged intermittent running protocol (23,24) and a soc-cer match (24). With the exception of knee extensor peak torque, small to moderate reductions from baseline values remained for all measures of muscle function alongside very large increases in soreness. These responses reflect EIMD imposed by prolonged intermittent exercise and, more importantly, suggest that participants started the second prolonged IHIR protocol with impaired functional capacity and muscle soreness.

During the second IHIR protocol performed 72 hours after the first, a key finding was the moderate to large increase in 10-m sprint time during the 90 minutes. This reduction in sprint performance might be attributed to the structural damage to the muscle fibers, which is confirmed by the immediate and prolonged losses in muscle function after IHIR-1. Preferential damage to type II muscle fibers is known to occur as a consequence of multiple eccentric contractions, which can be manifest as a reduction in sprint performance (18,24). Moreover, such damage would explain the elevated muscle soreness scores that remained from the first prolonged running bout. Increases in muscle soreness impose an inhibitory response that regulates vol-untary activation of the exercising musculature. This mech-anism has been reported as a reduced neural drive via stimulation of III and IV afferents and subsequent reduction in force generation to prevent further injury to the neuro-muscular system (22,27,41). Therefore, starting the second prolonged running protocol with sensations of muscle sore-ness likely played a similar role, such that participants downregulated the only self-regulated element in an attempt to work within tolerable limits.

A lower blood lactate response observed for blocks 1–5 during the second IHIR protocol is in contrast to work that has shown an increased [BLa] in the presence of EIMD (16). Our findings, however, are in agreement with those of Twist and Eston (39) who reported a lower [BLa] during a cycling time trial performed 48 hours after muscle-damaging exercise. Along with ; 3–5% reduction in mean heart rate in blocks 1–5, a lower [BLa] reaffirms that par-ticipants downregulated their maximal intensity efforts during the second IHIR protocol. That participants were able to increase their exercise intensity from block 5 to block 6 supports this notion further, with similar heart rates and [BLa] at block 6 for both running trials. This "end spurt" phenomenon has been reported previously for team sport athletes (40) and is indicative of participants con-serving energy expenditure before a final increase.

Participants' ratings of perceived exertion did not differ between the 2 IHIR trials, despite the reductions in the internal and external loads in the second trial. That is to say, participants provided the same perceived ratings of exertion in both IHIR bouts despite a voluntary downre-gulation of movement speed (i.e., sprint running) and con-comitant reductions in the heart rate and blood lactate response during the second IHIR bout. We propose that reductions in muscle force generating capacity and in-creases in muscle soreness as a consequence of the first IHIR are likely causes of this response. Indeed, these find-ings are consistent with those studies that report how symptoms of EIMD alter the association between effort perception and physiological response (25,39). Our data also reaffirm the importance of effort perception both in exercise regulation and its role in fatigue (12).

Although we used an intermittent test that has been widely adopted to simulate the activity patterns of various team sports (31), we are aware that the protocol did not involve any sideward and backward movements. Moreover, we did not include any assessment of player skill during the intermittent test. This means we are unable to understand the interactions between physiological, movement, and technical capabilities during prolonged exercise bouts sep-arated by short recovery periods. Having each participant wear a global positioning system (GPS) device would also have enabled a more intricate understanding of the move-ment characteristics during the intermittent running proto-cols. However, performing the trials indoors to standardize the running surface and avoid any influence of outdoor environmental conditions prevented the use of GPS.

PRACTICAL APPLICATIONS

This study has implications for practitioners concerned with athlete management during periods where 2 or more matches and/or high intensity training sessions are per-formed within close proximity. Exercise-induced muscle damage caused by an initial bout of prolonged intermittent exercise (a simulated soccer running protocol) appeared to encourage subelite team sport players to downregulate their efforts during a subsequent bout of the same duration and intensity. Coaches should therefore consider appropri-ate nutrition, recovery, and tactical strategies when the second bout of activity requires optimal performance. Where the focus is on training, coaches should be mindful of underrecovery from the initial bout of prolonged intermittent exercise and anticipate impaired sprinting performance in any subsequent bout as a conse-quence of an athlete's altered sense of effort influenced by increased muscle soreness.

Team sport athletes are frequently required to perform bouts of prolonged intermittent exercise separated by short recovery periods. Simulating the running intensities

of match play, we present novel data on how the physiological and perceptual responses to a second bout of prolonged intermittent exercise are altered after an initial bout of the same exercise performed 72 hours before. We report that subelite team sport players do not recover enough after an initial high-intensity intermittent running bout to enable replication of the same exercise intensity 72 hours later. Reductions in muscle force generating capacity and increases in muscle soreness appear immediately after the initial bout of intermittent high-intensity exercise and remain such that the players start the second bout still experiencing these symptoms. Consequently, players downregulate their all-out exercise efforts in an attempt to work within tolerable limits, the outcome of which is a lower physiological internal response with the same perception of effort. These data can be used to inform coaching practice during intense periods of competition or training.

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