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Fluid balance, thermoregulation and sprint and passing skill performance in female soccer players

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Ten females performed 90 min of the Loughborough Intermittent Shuttle Test (LIST) on two occasions separated by 7 days. Water [3 mL/kg body mass (BM)] was provided every 15 min during exercise (FL); no fluid was given in the other trial (NF). Participants performed the Loughborough Soccer Passing Test (LSPT) before and every 15 min during the LIST. Core temperature (T_c) was measured throughout using ingestible temperature sensors. Heart rate (HR), blood lactate ([La$^-$]) and ratings of perceived exertion (RPE) were collected at regular intervals during exercise. Participants experienced greater BM loss in NF (2.2 ± 0.4%) than FL (1.0 ± 0.4%; $P < 0.001$). Sprint performance deteriorated by 2.7% during exercise ($P < 0.001$) but there was no difference between trials ($P = 0.294$). No significant differences in LSPT performance were detected between trials ($P = 0.31$). T_c was higher during exercise in NF and was 38.6 ± 0.3 °C (NF) and 38.3 ± 0.3 °C (FL; $P < 0.01$) after 90 min. HR ($P < 0.001$), [La$^-$] ($P < 0.01$) and RPE ($P = 0.009$) were higher during exercise in NF. Ingesting water during a 90-min match simulation reduces the mild dehydration seen in female soccer players when no fluid is consumed. However, there was no effect of fluid ingestion on soccer passing skill or sprint performance.

There are substantial differences in both the physiological demands of women's football and the thermoregulatory responses of female players that may render current male recommendations and best practices inaccurate for females. It is well documented that women typically have lower sweating rates and electrolyte losses than men (Sawka et al., 1983; Burke & Hawley, 1997; Shirreffs, 1999). Moreover, the onset of sweating during intense exercise has been shown to occur at a higher core temperature in females than in males (Kenny & Jay, 2007). As a large component of metabolic heat generated during exercise is dissipated by the evaporation of sweat, these characteristics may present differing thermoregulatory issues for female players. Despite these potentially important sex-specific differences, fluid balance in women's soccer is not well researched (Rosenbloom et al., 2006). Indeed, hydration guidelines developed for male players are often applied to female players without modification (Maughan & Shirreffs, 2007).

In addition to the differing thermoregulatory responses outlined above, the demands of match play during the women's game are dissimilar to men's soccer. In high-level women's soccer, the pace of match play is typically less than that seen in the men's game (Kirkendall, 2007). Elite women also cover slightly less distance (10–11 km) on the pitch relative to their male counterparts (10–14 km; Mohr et al., 2003; Krustrup et al., 2005; Kirkendall, 2007). These unique demands and characteristics of the women's game further restrict the applicability of the findings and recommendations that are derived from male players.

Factors such as dehydration and elevated core temperature are known to influence the onset of fatigue during prolonged exercise (Reilly, 1997) while increasing the rating of perceived exertion (Montain & Coyle, 1992) and reducing the motivational drive to continue exercise (Bruck & Olschewski, 1987). Further, most measures of exercise performance are typically found to deteriorate at a level of dehydration equivalent to approximately 2% of the pre-exercise body mass (BM) (Maughan & Shirreffs, 2007), losses that are regularly experienced by soccer players during match play (Maughan et al., 2004). One reason for the dearth of knowledge in this area is the impracticalities associated with the use of traditional invasive methods of determining the core temperature. Players often view these techniques as unsanitary and they typically involve cables and cumbersome data-logging equipment. Recently, ingestible temperature sensors have been shown to be a valid and reliable method of quantifying core temperature during soccer-related activity (Gant et al., 2006), and this technique now extends the possibilities of research within this area. Despite these practical limitations associated with measuring heat stress, some laboratory-based studies have provided an insight into the issues outlined above using female games players and a well-controlled laboratory test (Loughborough Intermittent Shuttle Test; LIST; Morris et al., 2000; Sunderland & Nevill, 2005).

In male players, it has been shown that soccer dribbling performance deteriorates by 5% when dehydrated to 2.4% of the pre-exercise BM (McGregor et al., 1999). Similarly, sprinting performance (a fundamental ability required of a soccer player) is known to decrease during this 90-min protocol (McGregor et al., 1999; Ali et al., 2007b; Gant et al., 2007), as it does when fluid is restricted during match play (Mohr et al., 2003; Guerra et al., 2004). Alongside these decrements in performance, it is likely that during a period of disruption to hydration and thermoregulatory homeostasis, players' feelings of pleasure and perhaps motivation will decline (Backhouse et al., 2007), an area of exercise physiology in which knowledge is currently limited. Thus, there is a need to examine issues relating to skill and sprint performance, as well as perceptual responses during exercise, using female soccer players.

The purpose of the present study was to examine the influence of fluid intake on thermoregulatory responses and sprint and soccer-specific skill performance in female players during a 90-min simulated match play. Because of the differences reported, we hypothesize that fluid losses will be moderate during the protocol, and fluid ingestion will not influence core temperature, sprint and skill performance. This study adds novel female-specific data to the existing fluid-balance literature and explores in detail the changes that occur in thermoregulatory and performance variables during prolonged high-intensity exercise.

Materials and methods

Participants

Ten healthy female soccer players [age 25.5 ± 5.2 years, height 1.68 ± 0.05 m, BM 63.5 ± 5.7 kg and estimated maximal oxygen uptake ($\dot{V}O_{2max}$) 47 ± 4 mL/kg/min; mean ± standard deviation (SD)] volunteered to participate in the study. All participants had played at the local Premier Division standard or higher, with three National representatives. Players were from a range of outfield playing positions and were involved in regular training and match-play. All procedures had prior approval by Massey University's Ethical Advisory Committee. Following completion of a health-screening questionnaire, written informed consent was obtained from all participants. In order to be considered for inclusion in this study, participants were required to have regular menstrual cycles and be free of injury or chronic disease.

Preliminary procedures

During the first preliminary session, along with height and BM measurements, $\dot{V}O_{2max}$ was estimated by means of the multistage fitness test (Ramsbottom et al., 1988). In the second preliminary session, participants were required to perform 2 × 15 min blocks of the prolonged intermittent high-intensity shuttle-running protocol (LIST), to further familiarize themselves with the various experimental procedures. During both sessions, players were fully familiarized with the skill test (LSPT). Based on previous information (Ali et al., 2008), players were allowed 10–12 attempts to ensure full familiarization with the protocol and that scores reflected that the learning component of typical variation had diminished.

Experimental procedures

Based on a menstrual cycle questionnaire, participants reported for main trials during the 2-week period before menstruation (typically the luteal phase of their respective cycle; Marsh & Jenkins, 2002). Participants completed two main trials separated by at least 7 days. The sequence of trials was randomized to counteract order effects. During one trial, participants ingested water at a rate equivalent to 3 mL/kg BM after every 15 min of exercise (FL); in the other trial, they were not given any water during the exercise protocol (NF). Participants were required to replicate dietary (food and fluid intake) and lifestyle (including exercise and sleep) factors for the 2 days before the main trials.

Figure 1 shows a schematic representation of the experimental protocol. Participants were required to swallow ingestible temperature sensors (described below) 8 h before reporting to the laboratory and were asked to arrive after observing a 3-h fast. Participants were also required to ingest 400 mL of water (Pump Putaruru Water, Putaruru, New Zealand) in the hour immediately before data collection. Upon arrival, each participant gave the principal investigator the empty 400 mL water bottle and the empty temperature sensor packet to aid in assuring the investigator that both had been ingested. They were encouraged to empty their bladders, and a 25 mL midstream urine sample was collected before determination of semi-nude (wearing only underwear) BM (model 04010159, Tanita Corporation, Tokyo, Japan). Urine samples were stored in plastic containers at −20 °C for later analysis of urine osmolality (Wescor 5500 Vapour Pressure Osmometer, Logan, Utah, USA). Following measurement of resting blood lactate concentration ([La^-]) via the finger-prick method (Lactate Pro, Arkray Ltd., Kyoto, Japan), and resting core temperature, participants indicated their pre-exercise perceptual scores (detailed below).

After a 10-min standardized warmup (consisting of approximately 1200 m of jogging, dynamic stretching and high-intensity activity), participants performed the pre-exercise skill tests; the first LSPT was used as a practice test and the second was recorded as the pre-exercise (0-min) performance score. The LSPT requires participants to complete 16 passes against colored targets, while maneuvering around a grid of cones and lines, as quickly as possible. Performance comprises time to complete the passes plus any additional penalty time for inaccurate passing or poor control of the ball (Ali et al., 2007a). We recently validated this test with a similar cohort of well-trained female players (Ali et al., 2008).

Approximately 15 min after the initiation of the warmup, participants completed six 15-min blocks of the LIST punc-

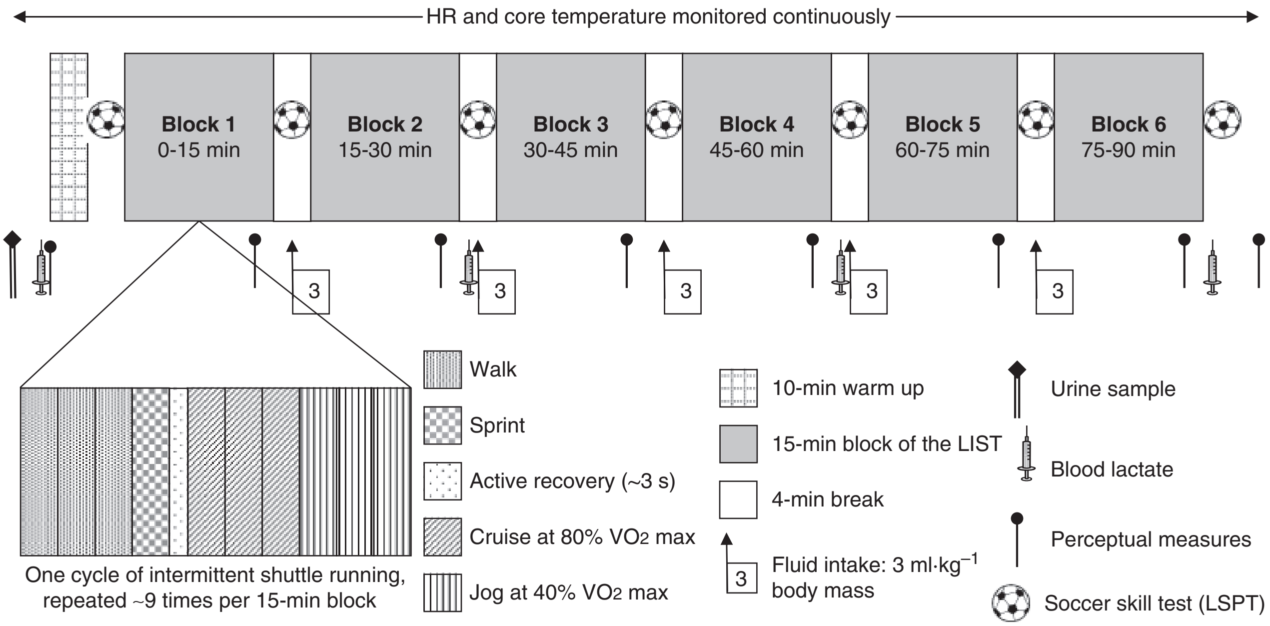

Fig. 1. Schematic representation of the experimental protocol.

tuated by 4-min rest periods. During these 4-min breaks, participants performed the LSPT and were required to consume the 3 mL/kg BM bolus of water (FL trial only; fluid temperature of 7 °C). Each 15-min block of the LIST consisted of approximately nine repeating cycles of walking, running (at a speed equivalent to 80% $\dot{V}O_{2max}$), jogging (at a speed equivalent to 40% $\dot{V}O_{2max}$) and sprinting; this was a modification of the original LIST protocol (Nicholas et al., 2000) to reflect the slightly reduced distance covered by female players (Mohr et al., 2003; Krustrup et al., 2005; Kirkendall, 2007). Fifteen-meter sprint performance was recorded during exercise via electronic timing gates specifically designed for this test. Heart rate (HR) was monitored continuously throughout exercise via short-range telemetry (Polar Electro S610i, Polar, Kempele, Finland). Blood lactate was measured after 30, 60 and 90 min of exercise. The participants were constantly encouraged to maintain the pace set by the audio signals and to perform maximally during the sprints. After completion of the LIST they were required to empty their bladders, towel dry and take a further semi-nude BM measurement.

Intestinal temperature measurement

Intestinal temperature was measured via disposable temperature sensor capsules (Cor-100, HQ Inc., Palmetto, Florida, USA). Participants ingested the sensor approximately 8 h before each trial; this has been shown to be sufficient to allow adequate progress of the sensor through the stomach and gastrointestinal tract to prevent vast changes in temperature resulting from ingested fluids (Gant et al., 2006). Where possible, participants were asked to ingest the sensor after defecating on the morning of testing to minimize the likelihood of the sensor being lost in fecal waste before testing. A resting core temperature reading was obtained upon arrival at the laboratory to ensure that the sensor was present in the intestines and activated. These values were also used to confirm that resting core temperature was similar between sessions and unchanged by events occurring between trials, such as ovulation. Core temperature was then measured every $\sim$ 80 s ($\pm$ 51 s) during each walking phase of the LIST, through the transmission of a signal to a data logger (Cor-Temp 2000, HQ Inc.) held near the lumbar region of the participant's torso. The electromagnetic signal extended to a radial proximity of approximately 60 cm; thus, measurements could be taken while participants were walking without causing interruption to the LIST protocol. The reading generated was then entered into a data spreadsheet for conversion into temperature.

Ingestible sensors were calibrated before the commencement of any main trials via the techniques previously described (Gant et al., 2004). Briefly, sensors were calibrated in a stirred water bath (Thermed 5001, GFL, Hannover, Germany), over a series of temperatures (37–39 °C), using a calibrated mercury thermometer (15–45 °C, LW Scientific, Lawrenceville, Georgia, USA). Sensors that resulted in $r < 0.999$ were not used in the experimental trials. A three-point linear regression was applied and the slope of the line was used to convert raw output from the sensors.

Perceptual measures

Thermal comfort was assessed by the Ratings of Thermal Sensation scale; a 15-point scale ranging from -4 ("cold") to 10 ("heat impossible to bear"). Gastrointestinal comfort and perceptions of thirst were monitored using two other 15-point Likert scales. These three scales were administered pre-exercise, during the walk phase of cycle 7 of each 15-min block of exercise and then post-exercise.

The Feeling Scale (FS; Hardy & Rejeski, 1989) was used as a measure of an affective dimension of pleasure–displeasure. This is a suitable assessment approach as changes in pleasure or activation status during exercise can impact on task persistence (Acevedo et al., 1996). The Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985) is a six-point, single-item measure of perceived activation/arousal and its use is valid because it assesses the participant's perception of his/her own bodily arousal/activation (Apter, 1988). Both the FS and the FAS have the advantage of being easily administered during exercise (see Backhouse et al., 2007). The 15-point Rating of Perceived Exertion scale (RPE) was used to assess perceived exertion during exercise and was administered every 15 min during exercise. The RPE scale was presented first, followed by the FS and then the FAS, during the last walk stage of each 15-min block of exercise.

Statistical analyses

A power analysis carried out based on a previous study by McGregor et al. (1999) indicated that 10 participants could allow an 80% chance of detecting a meaningful difference in LSPT performance. The data were examined using a two-factor (treatment × time of measurement) analysis of variance (ANOVA), with repeated measures for correlated data (SPSS Inc., Chicago, Illinois, USA, version 15). *Mauchly's test of sphericity* was used to determine whether the assumption of sphericity was being violated by the data. Where this did occur, the *Huynh–Feldt* correction was applied. When differences were identified by means of ANOVA, paired Student's *t*-tests using the Holm-Bonferroni adjustment were used to ascertain where the differences lay. Data are presented as means ± SD. The level of significance was accepted at $P<0.05$.

Results

Participants completed approximately 10.8 km during the 90-min LIST protocol per trial. The participants also performed 54 sprints, which made up approximately 800 m or 7% of the total distance covered. Environmental temperature (17.7 ± 1.4 °C and 17.2 ± 1.4 °C) and relative humidity (58 ± 9% and 62 ± 8%) were similar between trials and remained essentially constant during each trial. Data analyses on all Trial 1 vs Trial 2 data revealed no significant differences and therefore any differences between conditions are likely due to treatment effects and not trial order effects.

Fluid balance

Participants experienced greater BM loss in NF relative to FL (1.4 ± 0.3 kg vs 0.6 ± 0.3 kg; $P<0.001$), and there was 2.2 ± 0.4% and 1.0 ± 0.4% BM loss in NF and FL, respectively ($P<0.001$). The calculated fluid losses (corrected for fluid intake) were similar between NF (0.8 ± 0.1 L/h) and FL (0.7 ± 0.1 L/h; $P = 0.17$). There was an interaction of treatment × time for urine osmolality ($P = 0.015$). More specifically, urine osmolality decreased from 253 ± 180 to 187 ± 136 mOsmol/kg in FL but increased from 219 ± 185 to 394 ± 241 mOsmol/kg in NF.

Measures of performance

Fifteen-meter sprint performance deteriorated over time throughout both trials ($P<0.001$). Although sprint performance appeared to be faster in FL (2.85 ± 0.05 s) compared with NF (2.90 ± 0.03 s) throughout the 90-min exercise protocol, there was

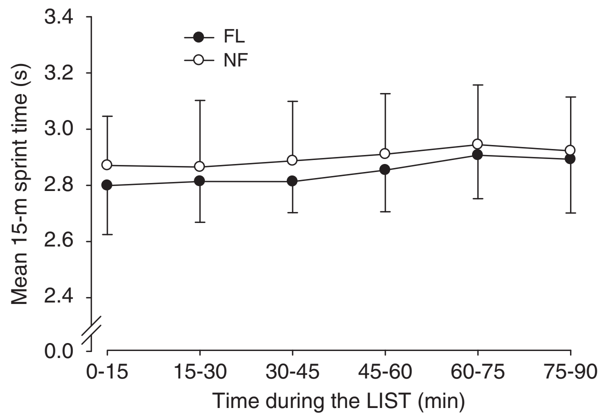

Fig. 2. Mean 15-m sprint performance during the simulated soccer exercise (LIST) in the fluid (FL) and no-fluid (NF) trials. LIST, Loughborough Intermittent Shuttle Test.

no main effect of treatment ($P = 0.294$) or interaction of treatment × time ($P = 0.733$; Fig. 2).

The overall LSPT performance consists of the time taken to complete each trial and any penalty time accrued for inaccurate passing and/or poor control of the ball (Table 1). There were no differences in the movement time between trials or during exercise. There were no differences in the penalty time between FL and NF but there was a main effect of time, with significantly lower values pre-exercise than during exercise ($P<0.05$). However, there were no main effects or interaction effect for the overall LSPT performance (Table 1).

Physiological measures

Intestinal temperature was 37.5 ± 0.5 °C at the start of the LIST and increased significantly with the duration of exercise (main effect of time, $P<0.001$). There was a main effect of treatment, with intestinal temperature significantly elevated during NF (38.5 ± 0.4 °C) compared with FL (38.3 ± 0.3 °C; $P = 0.05$; Fig. 3). Furthermore, there was an interaction of treatment × time ($P<0.001$) and, after 90 min of exercise, the intestinal temperature was significantly higher in NF (38.6 ± 0.3 °C) compared with FL (38.3 ± 0.3 °C; $P<0.05$). There was no difference in the change in the intestinal temperature at the beginning of the 90-min exercise protocol in FL and NF (0.4 ± 0.2 °C and 0.4 ± 0.3 °C, respectively). However, at the end of the exercise, the mean difference in the change in the intestinal temperature was higher in NF (1.1 ± 0.5 °C) compared with FL (0.9 ± 0.3 °C, interaction of treatment × time, $P<0.05$).

The mean HR during exercise was higher in NF (168 ± 2 beats/min) compared with FL (162 ± 1 beats/min; $P<0.001$). There was also a trend for HR to increase during exercise in NF but to remain relatively constant throughout the LIST in FL (interaction of

Table 1. Movement, penalty and total performance time for the soccer passing test (LSPT) at various points during exercise in the fluid (FL) and no-fluid (NF) trials

	Exercise time during the LIST (min)						
	Pre-exercise	15	30	45	60	75	90
Movement time (s)							
FL	50.3 ± 7.9	51.4 ± 6.4	48.5 ± 6.0	50.6 ± 6.2	50.5 ± 6.2	50.2 ± 6.2	50.5 ± 5.9
NF	52.5 ± 4.3	50.8 ± 5.0	50.4 ± 4.4	50.3 ± 5.6	49.7 ± 4.6	50.2 ± 5.3	51.5 ± 5.5
Penalty time (s)							
FL	29.7 ± 11.5	32.4 ± 9.4	29.4 ± 10.7	31.2 ± 6.7	29.0 ± 7.6	33.7 ± 6.6	31.0 ± 11.1
NF	27.6 ± 9.1	30.5 ± 11.6	31.7 ± 9.1	29.3 ± 10.6	30.7 ± 10.1	27.5 ± 13.5	34.8 ± 9.3
Total performance time (s)							
FL	80.0 ± 17.8	83.8 ± 13.6	78.0 ± 14.8	81.8 ± 11.9	79.5 ± 10.0	83.9 ± 8.1	81.5 ± 14.3
NF	80.0 ± 11.5	81.4 ± 12.6	82.1 ± 11.6	79.6 ± 13.2	80.4 ± 13.8	77.7 ± 16.9	86.3 ± 14.1

LIST, Loughborough Intermittent Shuttle Test.

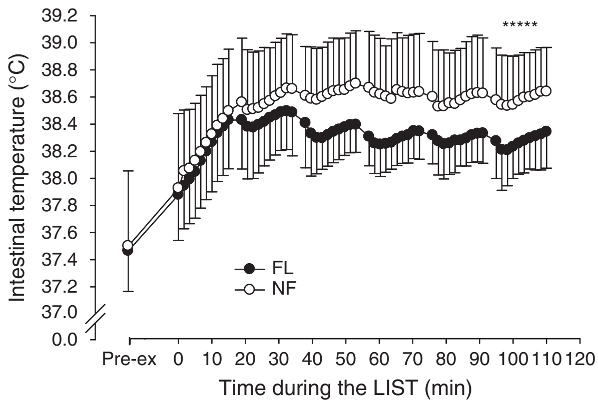

Fig. 3. Intestinal temperature readings during the simulated soccer exercise (LIST) in the fluid (FL) and no-fluid (NF) trials (NB the time scale on the *x*-axis includes 4-min rest periods between exercise time during the LIST; *significantly higher than FL; $P<0.05$). LIST, Loughborough Intermittent Shuttle Test.

treatment × time; $P=0.06$); at the end of the exercise, HR was 171 ± 9 beats/min and 163 ± 9 beats/min in NF and FL, respectively (Table 2).

The blood lactate concentration increased during the 90 min of exercise in both trials (main effect of time; $P<0.001$) and was markedly higher in NF (7.2 ± 5.5 mM) compared with FL (3.7 ± 2.7 mM; $P<0.01$). Furthermore, there was an interaction of treatment × time, with [La^-] higher in NF after 60 ($P<0.05$) and 90 min ($P<0.001$) of exercise (Table 2).

Perceptual responses

Although there was no main effect of treatment, ratings of perceived thermal strain increased with the duration of exercise ($P<0.001$). Moreover, there was an interaction of treatment × time ($P=0.002$) with *post hoc* analyses revealing significant differences between NF and FL during block 5 of exercise and post-exercise [$P<0.05$; Fig. 4(a)]. Ratings of perceived exertion (RPE) were higher in NF (13.7 ± 2.3) than FL (12.5 ± 2.0; $P=0.009$) and increased with duration of exercise ($P<0.001$). Furthermore, there was an interaction of treatment × time ($P=0.007$) with *post hoc* analyses showing significant differences between trials in blocks 1, 5 and 6 [$P<0.05$; Fig. 4(b)]. There were no differences in the mean ratings of pleasure/displeasure between FL (2.1 ± 1.5) and NF (1.6 ± 1.8; $P=0.11$). However, there was a significant main effect of time, with participants feeling worse with the duration of exercise ($P<0.001$). There was also a trend for an interaction of treatment × time, with participants appearing to feel worse in NF with the duration of exercise ($P=0.06$). There were no differences in perceived activation ratings between FL (3.5 ± 1.1) and NF (3.3 ± 1.0; $P=0.26$), and the values remained constant throughout exercise ($P=0.85$). Participants felt thirstier in NF (12.4 ± 3.7) than FL (9.2 ± 2.3; $P=0.002$) and generally thirstier with the duration of exercise (main effect of time; $P<0.001$). An interaction effect was also present ($P<0.001$), with participants feeling thirstier in NF from block 4 of exercise onwards [$P<0.05$; Fig. 4(c)]. Ratings of gut fullness were not different between FL (10.1 ± 2.9) and NF (9.0 ± 2.5; $P=0.28$), and the values remained unchanged throughout both trials ($P=0.55$).

Discussion

The main aims of this study were to investigate the influence of fluid intake on thermoregulation and soccer performance in female players during and following 90 min of intermittent high-intensity shuttle running. Fluid ingestion offset the small levels of

Table 2. Mean heart rate (HR) and blood lactate ([La$^-$]) concentrations during the simulated soccer exercise (LIST) in the fluid (FL) and no-fluid (NF) trials

	Pre-exercise	Exercise time during the LIST (min)						
		0–15	15–30	30–45	45–60	60–75	75–90	Trial mean
Heart rate (beats/min)								
FL	72 ± 6	161 ± 12	163 ± 10	163 ± 10	163 ± 10	162 ± 9	163 ± 9	162 ± 1
NF	75 ± 9	166 ± 13	168 ± 11	167 ± 11	167 ± 9	171 ± 11	171 ± 9	168 ± 2*

	Pre-exercise	30	60	90	Trial mean
Blood lactate (mmol/L)					
FL	1.1 ± 0.3	4.7 ± 2.9	4.5 ± 2.3	4.5 ± 2.9	3.7 ± 2.7
NF	1.3 ± 0.6	7.1 ± 3.4	8.2 ± 4.4*	10.2 ± 3.9*	7.2 ± 5.5*

*Significantly higher than FL, $P<0.05$.
LIST, Loughborough Intermittent Shuttle Test.

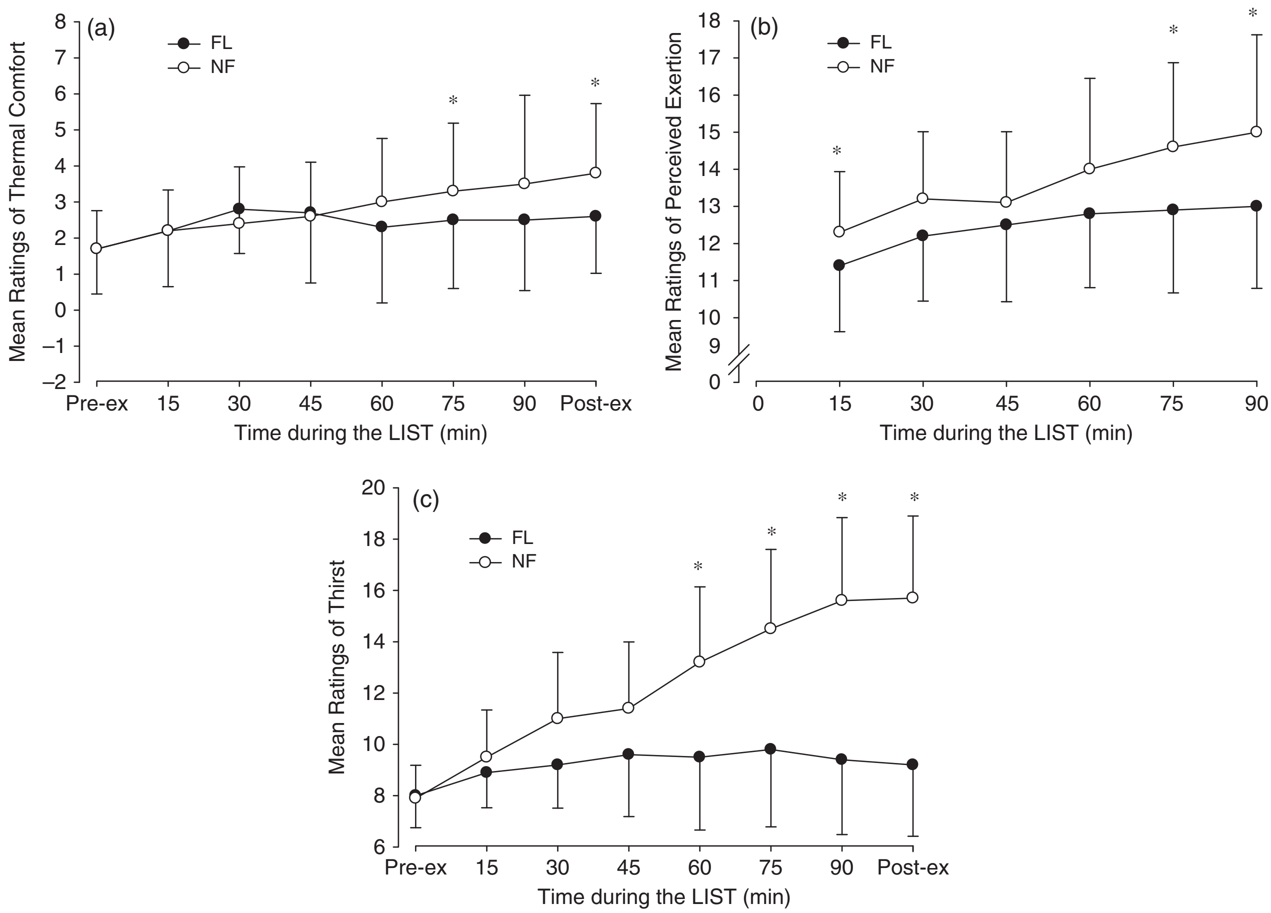

Fig. 4. Perceptual responses during the simulated soccer exercise (LIST) in the fluid (FL) and the no-fluid (NF) trials; (a) thermal comfort; (b) exertion (RPE); and (c) thirst drive (*significantly different from FL; $P<0.05$). LIST, Loughborough Intermittent Shuttle Test.

dehydration observed in NF and led to favorable physiological (reduced core temperature and cardiovascular strain) and perceptual responses during and following exercise. However, contrary to previous findings in male participants, fluid ingestion did not lead to better sprint and skill performance, relative to NF, in female soccer players.

Dehydration by as little as 2% has been purported to reduce exercise performance and have adverse effects on health (Maughan & Shirreffs, 2007) and so athletes are encouraged to replace fluid lost as sweat during exercise. It is also well established that females have lower sweat rates than males (Sawka et al., 2007). In a similarly designed study, the sweat losses of male players (1.2–1.4 L/h; McGregor et al., 1999) were higher than the sweat losses of the female players in the current investigation (0.7–0.8 L/h). Therefore, to offset the potential issues relating to dehydration, and consistent with recent ACSM guidelines (Sawka et al., 2007), participants in the current study were given water at a rate of 0.5 L/h during exercise in FL. This led to only 1.0% BM loss, and similar urine osmolality values from pre- to post-exercise, suggesting that hydration status was relatively well maintained during exercise. In the NF condition, participants' BM decreased by 2.2% and urine osmolality values significantly increased (relative to FL) post-exercise.

Sprinting ability is a fundamental trait required of a soccer player as it contributes approximately 8–12% of the total distance covered during match-play (Guerra et al., 2004). In addition, individuals who train the sprint component of their physical fitness may likely be set apart from players who are unable to reach the ball first in order to perform the necessary skills to defeat the opposition. In the present study, although sprint performance deteriorated by 2.7% throughout the 90-min protocol, there was no difference between trials (Fig. 2). In contrast, using male players, McGregor et al. (1999) showed a significant reduction in sprint performance toward the later stages of the LIST. Moreover, the ability to maintain skillful play throughout exercise can be suggested to be a key aspect in winning soccer matches. McGregor et al. (1999) showed that soccer dribbling performance was better maintained in male players when water was provided during high-intensity exercise. However, in the current study, fluid ingestion did not affect soccer passing skill performance relative to the no-fluid condition (Table 1). Thus, it appears that soccer passing skill and sprint performance in female players are fairly robust during a high-intensity, soccer-type exercise under temperate conditions. The reasons for this may relate to the reduced energy expenditure (Kirkendall, 2007) and/or the lower sweat rate (Sawka et al., 1983; Burke & Hawley, 1997; Shirreffs, 1999) seen in females during soccer; however, this warrants further research.

In the current study, sprint performance deteriorated over time in both FL and NF (Fig. 2), suggesting that factors other than hydration status were responsible for this reduced work rate. There is a large body of evidence in support of the role that carbohydrate plays in the maintenance of performance during high-intensity exercise. It is possible that participants' glycogen stores were depleted during both trials in the present study as has been shown in male participants following the LIST (Nicholas et al., 1999). It is therefore feasible that sprint performance in the current study may not have deteriorated over time if carbohydrate was included in the fluid consumed throughout exercise (cf. Ali et al., 2007b; Gant et al., 2007). As there is a dearth of information relating to carbohydrate ingestion and sprint and skill performance in female soccer players there is a need for research in this area.

Hoffman et al. (1994) showed that a BM loss of 1–2% contributed to an elevation in core temperature as well as cardiovascular strain. In the current study, intestinal temperature was significantly lower with fluid ingestion and was 38.6 °C and 38.3 °C at the end of exercise in NF and FL, respectively (Fig. 3). These values are similar to core temperatures of 38.7 °C recorded in Danish National League female players at the end of match play (Davis & Brewer, 1993). However, the average core temperatures ranged from 39.0 to 39.5 °C in male soccer players during a game (Ekblom, 1986) and during the LIST (Gant et al., 2004, 2006, 2007). This suggests that soccer-type activity places a greater demand on thermoregulation in male than female players and could be the reason why sprint and skill performance are more likely to be affected in the former.

Under these particular environmental conditions (17–18 °C, 60% RH), peak core temperature values recorded following NF were of a magnitude that is unlikely to result in any of the negative performance or safety outcomes that are typically associated with a high core temperature. However, under more stressful environmental conditions that female soccer players from temperate climates may encounter when competing within hotter and more humid conditions, core temperature could increase to a higher level and perhaps reach the threshold that is known to limit exercise performance and capacity. Research indicates that athletes under compensable heat loads become fatigued when the core temperature reaches around 40 °C (Gonzalez-Alonso et al., 1999). A number of LIST-based studies suggest that 39.5 °C is the core temperature that coincides with the point of exhaustion in female games players (Morris et al., 2000; Sunderland & Nevill, 2005). The intestinal temperatures of participants in the present study (38.3–38.6 °C) were notably lower than this. It is possible that if the environmental temperature increased, or extra periods of play were added to a match, without allowing players the opportunity to replace sweat losses, these changes may have been of a magnitude that would influence sprint and skill performance.

The mean HR during elite female soccer has been shown to be 167 beats/min (Krustrup et al., 2005). Further, HR increases by around 3–5 beats/min for every 1% of pre-exercise BM lost (Montain & Coyle, 1992). The results of the current study support these earlier findings, i.e. the mean HR was 168 and 162 beats/min in NF and FL, respectively (Table 2); the higher HR in NF likely due to dehydration-induced reduction in the plasma volume (Hamilton et al., 1991). The blood lactate concentration was also significantly higher at the end of exercise in NF compared with FL (Table 2) and is similar to the values reported during match play (Krustrup et al., 2005). Significantly higher [La$^-$] were also found in the no-fluid condition when female games players exercised in the heat (Morris et al., 2000; Sunderland & Nevill, 2005). The higher [La$^-$] during NF supports the other variables that indicate that the level of metabolic stress (Hargreaves et al., 1996) was considerably greater when fluid was restricted during this protocol.

It has been reported that the women's game is performed at a lower intensity than the men's game (Kirkendall, 2007). Match analyses have revealed that female soccer players perform less than two-thirds of the high-intensity exercise and sprinting distance evident in the male game (Mohr et al., 2003). A number of studies have been successfully completed using the LIST protocol with female games players (Morris et al., 2000; Sunderland & Nevill, 2005). However, the relative exercise intensities dictated by the generic LIST protocol did not reflect the demands of the games in which our cohort regularly compete, nor did it elicit the same physiological responses. For these reasons, a number of pilot trials using modified LIST exercise protocols were undertaken with female players to determine appropriate intensities for which each activity was to be performed. As a result, the intensities used during the running and jogging phases of the test (80% and 40% $\dot{V}O_{2max}$), and the walking speed, were modified accordingly. During the modified protocol, participants complete 10.8 km, a distance that falls within those covered by elite female players during match play (Davis & Brewer, 1993; Mohr et al., 2003; Krustrup et al., 2005). HR and blood lactate data obtained during the current study also indicate that the modified LIST protocol places adequate physical strain on female players and thus is a sound method of simulating the demands of actual match play. Nevertheless, it must be noted that the players in the current study had lower $\dot{V}O_{2max}$ than those from whom the match analysis data were taken from (Mohr et al., 2003; Krustrup et al., 2005).

It is known that dehydration and subsequent elevations in core temperature increase RPE (Montain & Coyle, 1992) and inhibit motivation to continue exercise (Gopinathan et al., 1988). Our data support these notions as RPE increased throughout exercise and was significantly higher when fluid was restricted during exercise [Fig. 4(b)]. Moreover, ratings of thermal comfort [Fig. 4(a)] and thirst drive [Fig. 4(c)] were significantly higher in NF than FL. These data support the physiological variables that were elevated in NF and indicate that dehydration and the subsequent increased physiological strain were manifest in the subjective experiences of players. Despite the regular ingestion of fluid, no differences were detected in gut fullness between trials. This indicates that the fluid replacement regimen – based on current recommendations (Sawka et al., 2007) and at a rate that was considered to be near the maximum tolerable volume during this form of exercise – did not negatively influence the gastrointestinal comfort of players, an important consideration during protocols that include self-selected performance.

In summary, ingesting water during a 90-min match simulation reduces the moderate dehydration seen in female soccer players when no fluid is consumed. Fluid ingestion attenuates the increase in intestinal temperature and reduces cardiovascular strain, blood lactate concentrations and perceptions of exercise intensity. However, fluid ingestion was unable to offset decline in sprint performance. In addition, there was no effect of fluid ingestion on soccer passing skill performance.

Perspectives

Dehydration has been shown to reduce soccer skill (McGregor et al., 1999) and sprint performance (McGregor et al., 1999; Ali et al., 2007b; Gant et al., 2007) in male players. However, there are substantial differences in both the physiological demands of the women's game (Kirkendall, 2007) and the thermoregulatory responses of female players (Burke & Hawley, 1997; Shirreffs, 1999) that may render current male recommendations and best practices inaccurate for females (Maughan & Shirreffs, 2007). The present study shows that water ingestion that offsets mild dehydration during a soccer-type activity reduces the core temperature and cardiovascular strain, while maintaining heightened perceptual responses, in female players. However, water ingestion was unable to offset the deterioration in sprint performance throughout the 90-min exercise protocol. Soccer passing skill performance was fairly robust within this cohort as there were no differences in performance between trials or over time.

Key words: core temperature, dehydration, LIST, LSPT, passing, sprinting, women's football.

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