

Ingestion of High Carbohydrate Meal with Low Glycaemic Index improves Repeated Sprint Performance in Elite Adult Female Soccer Players

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The aim of the current study was to examine an influence of high carbohydrate (CHO) pre-exercise meal with various glycaemic index (GI) on repeated sprint performance during a soccer match simulated prolonged high intensity intermittent running in trained adult female soccer players. This study was crossover design and eight trained female soccer players consumed isoenergetic high CHO meal with either high GI (HGI) (GI = 76) or low GI (LGI) (GI = 44) which provided 2 g CHO·kg⁻¹ body mass 3 hours before performing the Loughborough Intermittent Shuttle Test (LIST). The test involved five 15-minute blocks and an open ended block which consisted of walking, jogging, cruising and 15 m sprint. Sprint time was significantly faster during the LGI trial than the HGI trial (HGI vs. LGI = 2.96 ± 0.06 s vs. 2.89 ± 0.06 s, *p* < 0.05). Heart rate (180 ± 2 beats·min⁻¹ vs. 176 ± 3 beats·min⁻¹, *p* < 0.05) and RPE (15.3 ± 1.8 vs. 14.2 ± 2.2, *p* < 0.05) were significantly lower during the LGI trial compared to the HGI trial. Therefore, female soccer players are advised to consume a high CHO meal with LGI before training or match.

Keywords: association football, exhaustion, intermittent sport, sports nutrition

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1. Introduction

There have been a large number of studies conducted on the effect of carbohydrate ingestion before, during and after exercise (Rankin, 1997). It is now widely accepted that endurance capacity and performance, and high intensity intermittent exercise capacity can be enhanced by ingesting carbohydrate (CHO) before and during exercise by making very positive contribution to substrate availability (Coyle, 2004). Moreover, a consumption of CHO immediately after exercise enhances the recovery rate (Ivy, 1999). As the positive effect of CHO on exercise and recovery has been discovered, the interest of researchers shifted to the type of CHO to be consumed. Glycaemic index (GI) is one way to differentiate between different types of CHO.

Many studies have investigated the effect of high CHO pre-exercise meal with varied GI on exercise performance, exercise capacity and/or metabolism during the exercise (Thomas, Brotherhood and Miller, 1994; Febbraio & Stewart, 1996; Sparks et al., 1998;

DeMarco, Sucher, Cisar, and Butterfield, 1999; Wee, Williams, Gray, and Horabin, 1999; Febbraio, Keenan, Angus, Campbell, and Garnham, 2000; Stannard, Constantini, and Miller, 2000; Kirwan, Cyr-Campbell, Campbell, Scheiber, and Evans, 2001a; Wu, Nicholas, Williams, Took, and Hardy, 2003). During endurance exercise, many studies reported some influence of GI on exercise performance (DeMarco et al., 1999; Moore, Midgley, Thurlow, Thomas, and McNaughton, 2009; Stannard et al., 2000; Kirwan et al., 2001a), exercise capacity (Thomas et al., 1994), fat oxidation (Stevensson et al., 2006; Wee et al., 1999), increased fatty acid, glycerol or ketone body concentrations (Febbraio & Stewart, 1996; Febbraio et al., 2000; Sparks et al., 1998; Stevensson et al., 2006). In contrast, some studies found no influence of GI on exercise performance (Febbraio & Stewart, 1996; Sparks et al., 1998; Febbraio et al., 2000), exercise capacity (Wee et al., 1999; Karamanolis, Laparidis, Volaklis, Douda, and Tokmakidis, 2011; Kirwan et al., 2001b), CHO oxidation (Moore et al., 2009;), fat oxidation (Moore et al., 2009;) and fat metabolites (Moore et al., 2010; Stevenson, Williams,

and Nute, 2005). The reason for the inconsistency between studies may be due to the differences in amount of CHO consumed, intensity of exercise, timing of the consumption of pre-exercise meal and type of exercise employed (Wu et al., 2003).

Although many studies have examined influences of high CHO meal with various GI on endurance exercise, there is only a few studies examined the effect of GI on intermittent exercise (Bennett et al., 2012; Hulton, Gregson, Maclaren, and Doran, 2012; Little, Chilibeck, Ciona, Vandenberg, and Zello, 2009; Little et al., 2010). The studies ingested high CHO meal with various GI before a 90 minute intermittent exercise which took place on a treadmill and was designed to simulate the activity pattern of a soccer match by alternating between periods of rest (7%), walking (56%), jogging (30%), running (4%) and sprinting (3%) (Drust, Reilly, and Cable, 2000). The studies assessed performance by five 1 minute sprints conducted in the last 15 min of the intermittent exercise (Bennett et al., 2012; Little et al., 2009; Little et al., 2010) or 1 km trial after the 90 minutes of intermittent exercise (Hulton et al., 2012). There are no studies which discovered differences in performance between HGI and LGI conditions although LGI condition showed a higher blood glucose concentration towards the end of intermittent exercise (Bennett et al., 2012). However, the studies has neglected an importance of ability to repeat short sprint during a soccer match and such importance has been shown during a professional soccer match as the players sprint ~40 times a match and the sprint distance ranges between 12.1 and 27.4 m with a mean of 18.4 m (Carling, Le Gall, and Dupont, 2012). Therefore, an employment of soccer simulated intermittent exercise which includes short sprints would probably be more applicable. Loughborough Intermittent Shuttle Test (LIST) is a soccer simulated prolonged high intensity intermittent running test which includes various types of exercises from stopping to sprinting and it is possibly more suitable exercise test than the protocols employed in the previous studies (Nicholas, Nuttall, and Williams, 2000). Furthermore, previous studies mainly employed recreational level adult males or mixture of adult male and female soccer players and no studies have employed trained female soccer players to examine influence of GI on high intensity intermittent running.

Therefore, the purpose of the current study was to examine influences of high CHO pre-exercise meal with various GI on repeated sprint performance during a soccer match simulated prolonged high intensity intermittent running on trained adult female soccer players.

2. Methods

2.1. Participants

Eight trained, healthy non-smoking female soccer players (mean \pm SD, age = 20.5 \pm 0.8 years, body mass = 61.0 \pm 5.3 kg, $\dot{V}O_{2max}$ = 50.6 \pm 2.7 ml·kg⁻¹·min⁻¹) volunteered to take part in the study. The demands and possible risks associated with the study were explained to all participants verbally and in written form. All participants gave their written informed consent to take part in the study and completed the health history questionnaire. None of participants were on medications or had serious health problems. The study was approved by a University Ethical Committee.

2.2. Preliminary measurements

Participants' $\dot{V}O_{2max}$ was estimated by using the progressive shuttle run test which was employed to estimate 55% and 95% $\dot{V}O_{2max}$ using the tables for predicted $\dot{V}O_{2max}$ values (Ramsbottom, Brewer, and Williams, 1988). After the test, participants rested for 15-30 minutes and then performed the LIST for 15 minutes to familiarise themselves with the protocol. A day before the trial, participants reported to the laboratory to measure their body mass. The body mass was used to calculate the meal size for the trial.

2.3. Test meals

High CHO meal with HGI or LGI was provided in each trial (**Table 1**). Both meals provided similar amount of macronutrients containing 2 g CHO·kg⁻¹ body mass. The macronutrient content of the meals was 82-83% CHO, 12-14% protein and 5-6% fat. The GI values used for the calculation were taken from the international table of GI and glycaemic load values (Foster-Powell, Holt, and Brand-Miller, 2002). Weighted means of GI values for each component of

Table 1 Test meal characteristics for 60 kg participant

	HGI meal	LGI meal
Description	53g Corn Flakes [#] , 220ml skimmed milk, 68g white bread, 9g flora, 18g jam, 132ml Lucozade Original drink [†]	74g muesli, 220ml skimmed milk, 57g apple, 88g tinned peaches, 110g yoghurt, 220ml apple juice
Energy (kcal)	620	623
CHO (g)	119	119
Protein (g)	18	21
Fat (g)	8	7
GI	76	44

[#]Corn Flakes: Kellogg's (UK) Ltd. Manchester UK. [†]Lucozade Original drink UK

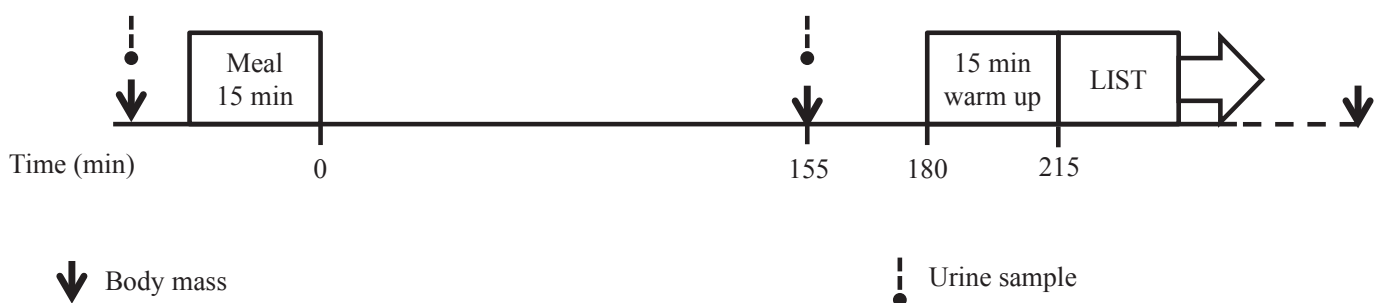
food were used to calculate the GI of total food for each meal (Wolever and Jenkins, 1986).

2.4. Experimental design

All participants took part in two trials and they were fed high CHO meal with HGI or LGI in each trial. The trials were randomised crossover design and counterbalanced with at least 7 days separation. During 2 days before the trial, participants refrained from strenuous exercise and did not consume caffeine or alcohol. During 2 days before the first trial, participants recorded their food intake to replicate the same food intake for the second trial. During the postprandial period of the first trial, participants were free to drink as much water as they required. This amount of water was consumed in the second trial to replicate the same fluid intake.

2.5. Experimental protocol

Participants reported to the laboratory between 07:00 and 08:00 of the trial day after at least 10 hours overnight fast. Their nude body mass was measured using a beam balance (Avery, Birmingham, UK) after collecting urine sample and emptying their bladder. Then participants consumed LGI or HGI meal in 15 minutes and postprandial period started (0 min). At 155 minute, nude body mass was measured and urine sample was taken. After 3 hours of postprandial period, 15 minutes standardised warm up was performed and the LIST was initiated. Verbal encouragement was given during the LIST and up tempo music was played during part A. After completing the LIST, dried nude body mass of participants was measured (**Figure 1**). Wet and dry temperatures were recorded every 30 minutes using

**Figure 1** Experimental protocol.

whirling hygrometer (Brannan thermometer Ltd, Cumberland, UK) during the trials. During 3 hours postprandial period, dry bulb temperature was 22-24°C and wet bulb temperature was 14.5-17.5°C. During the LIST, dry bulb temperature was 15.5-20.0°C and wet bulb temperature was 11-15°C.

2.6. Loughborough Intermittent Shuttle Test

The test took place in sports hall and the participants were required to run between two lines which were 20 m apart. There were infra-red photoelectric cells (RS Components Ltd, Switzerland) interfaced with microcomputer at the start and end of the sprinting line to measure the sprint time. The audio signal was given by microcomputer (BBC Master Series) using software developed for this purpose to enable participants to know the speed and timing of walking and running. The test was structured by part A and part B. In part A, there were five 15-minute blocks and participants were given 3-minute rest between the blocks and part B. Each block in Part A involved 11 cycles and each cycle consisted of 3 x 20 m walk, 1 x 15 m sprint, 4 seconds rest, 3 x 20 m running at a speed corresponding to 55% of individual $\dot{V}O_{2max}$ and 3 x 20 m running at a speed corresponding to 95% of individual $\dot{V}O_{2max}$, respectively. Part B was open-ended design to exhaust participants and each cycle consisted of 1 x

20 m walk, 1 x 15 m sprint, 4 seconds rest, 1 x 20 m running at a speed corresponding to 55% of individual $\dot{V}O_{2max}$ and 1 x 20 m running at a speed corresponding to 95% of individual $\dot{V}O_{2max}$, respectively. Part B was terminated when two consecutive sprint times were longer than 105% of a mean of all sprint time from block 2, 3 and 4 (Nicholas et al., 2000). The protocol was modified from what was described by Nicholas and colleagues (2000) to allow an assessment of a decline in repeated sprint performance (**Figure 2**).

2.7. Measurements during the LIST

Heart rate was recorded every 5 seconds (The team polar transmitter, Polar Electro, Finland) during the LIST and perceived rate of exertion (PRE) was recorded just after ninth sprint in every block during part A (Borg, 1973).

2.8. Statistical analysis

Data was analysed using PASW Statistics 18 software (SPSS, Chicago, IL, USA). A Kolmogorov-Smirnov test was employed to examine whether or not the distribution was normal and homogeneity of variance was examined using Levene's test. A two-way Analysis of Variance with repeated measures (treatment x time) was employed to examine the differences in variables between the trials except

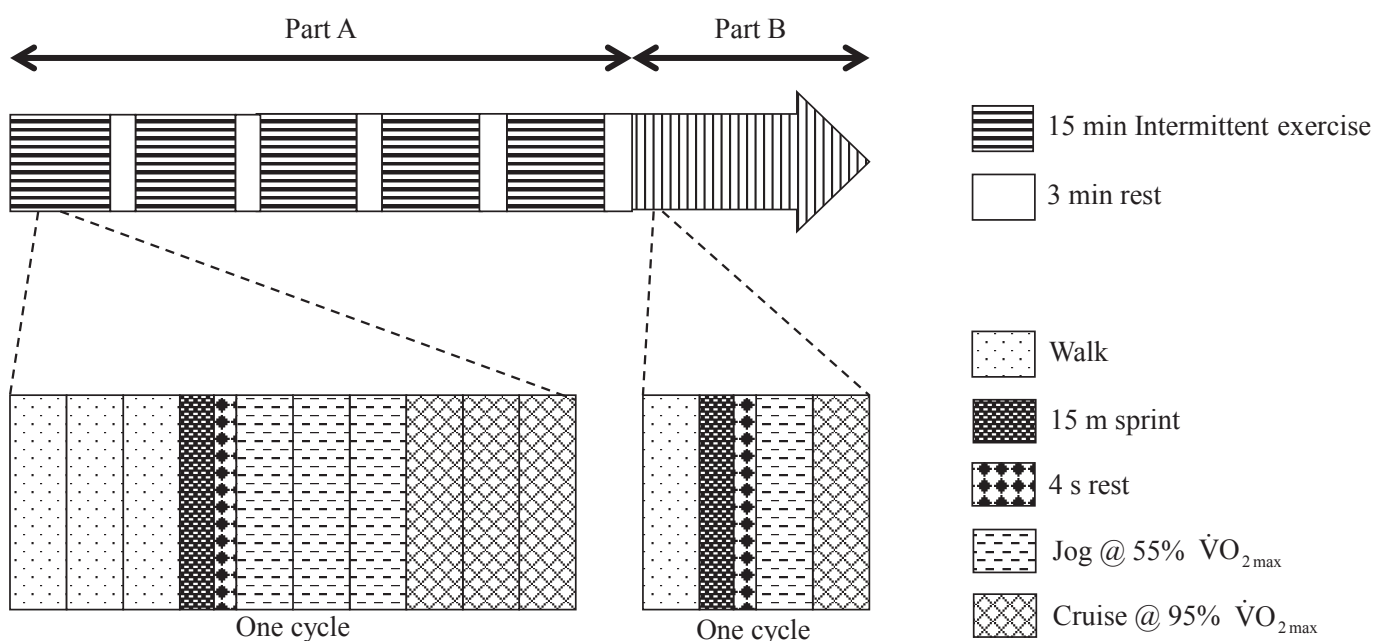


Figure 2 Schematic representation of the Loughborough Intermittent Shuttle Test protocol.

time to exhaustion which was examined by a paired sample t-test. Statistical significance was set at $P < 0.05$. All data are presented as mean \pm SD.

3. Results

There was no significant treatment \times time interaction for sprint time (**Figure 3**). However, mean time of all sprints during the LIST was significantly faster in the LGI trial than the HGI trial (treatment effect, HGI vs. LGI = 2.96 ± 0.06 s vs. 2.89 ± 0.06 s, $P < 0.05$). For time to exhaustion, there were no significant differences between the HGI and LGI trials (**Figure 4**). There was no significant treatment \times time interaction for heart rate but mean heart rate during the LIST was significantly lower in the LGI trial compared to the HGI trial (treatment effect, HGI

vs. LGI = 180 ± 2 beats \cdot min $^{-1}$ vs. 176 ± 3 beats \cdot min $^{-1}$, $P < 0.05$) (**Figure 5**). Moreover, there was a significant treatment \times time interaction for RPE ($P < 0.05$) and RPE was significantly lower during the LGI trial compared to the HGI trial (HGI vs. LGI = 15.3 ± 1.8 vs. 14.2 ± 2.2 , $P < 0.05$) (**Figure 6**). No other differences were found in mean sprint time, mean heart rate and RPE between the trials. There were no significant differences in body mass between the HGI and LGI trials at pre-meal (HGI vs. LGI = 60.9 ± 5.3 kg vs. 61.1 ± 5.3 kg), pre-LIST (61.3 ± 5.5 kg vs. 61.4 ± 5.3 kg) and post-LIST (60.6 ± 5.5 kg vs. 60.6 ± 5.6 kg). Moreover, no significant differences were found in urine osmolality between the HGI and LGI trials at pre-meal (HGI vs. LGI = 757.8 ± 311.9 mOsm \cdot kg $^{-1}$ and 774.1 ± 294.9 mOsm \cdot kg $^{-1}$) and pre-LIST (225.0 ± 170.2 mOsm \cdot kg $^{-1}$ and 243.6 ± 126.7 mOsm \cdot kg $^{-1}$).

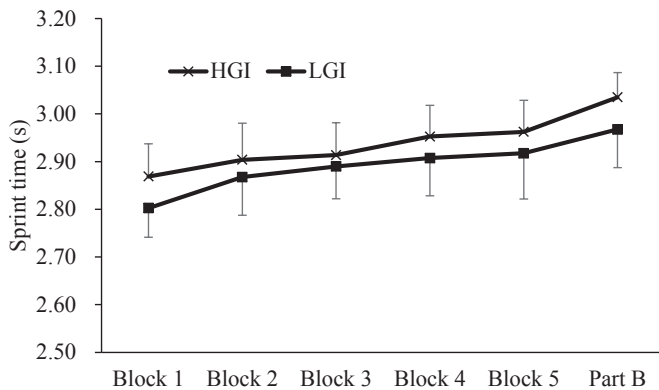


Figure 3 Mean sprint time from each block and part B. Mean time of all sprints during the LIST was significantly different between the trials (treatment effect, $P < 0.05$). No other differences were found.

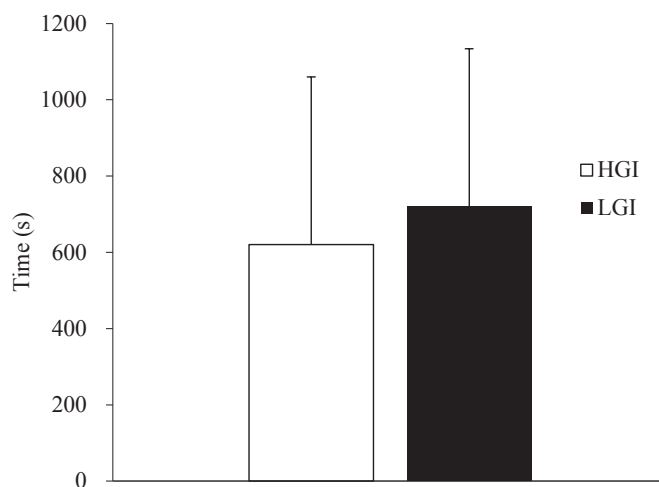


Figure 4 Time to exhaustion during part B.

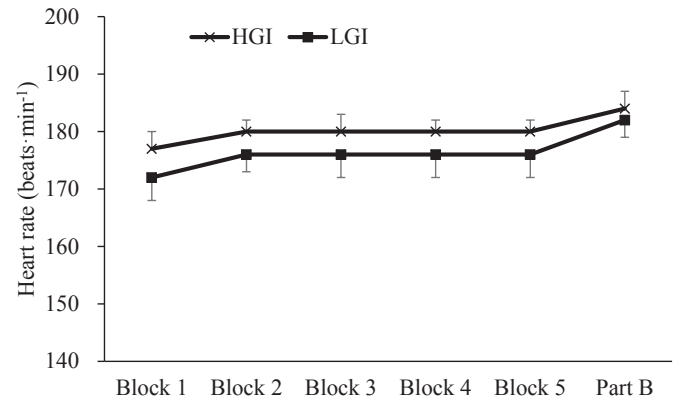


Figure 5 Mean heart rate from each block and part B. Mean heart rate during the LIST was significantly different between the trials (treatment effect, $P < 0.05$). No other differences were found.

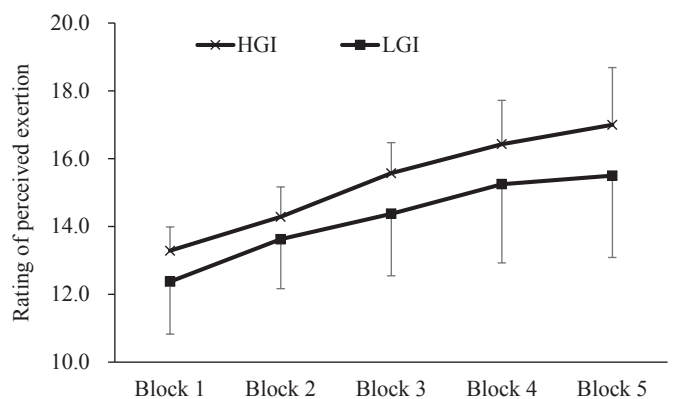


Figure 6 Mean RPE from each block. There was a significant treatment \times time interaction for ($P < 0.05$) and mean RPE during part A (block 1 to 5) was significantly different between the trials (treatment effect, $P < 0.05$). No other differences were found.

4. Discussion

The present study was the first to examine the effect of high CHO pre-exercise meal with various GI on repeated sprint performance during a soccer match simulated prolonged high intensity intermittent running with trained adult female soccer players. Key findings of the present study were that: 1) repeated sprint performance was faster after a consumption of LGI high CHO pre-exercise meal compared to a consumption of HGI high CHO pre-exercise meal during the LIST; 2) time to exhaustion did not differ between the LGI and HGI trials; and 3) heart rate and RPE were lower during the LGI trial compared to the HGI trial. The findings regarding the faster repeated sprint performance and, lower heart rate and RPE in the LGI trial compared to the HGI trial during the LIST are novel findings and the results do not support previous studies which reported that GI of pre-exercise meal does not influence sprint performance during a soccer match simulated 90-minute high intensity intermittent running (Bennett et al., 2012; Little et al., 2009; Little et al., 2010). However, the current and previous studies demonstrated no differences in time to exhaustion between the LGI and HGI trials during the high intensity intermittent running (Bennett et al., 2012; Hulton et al., 2012; Little et al., 2009; Little et al., 2010).

The participants' body mass before the meal, before and after the LIST were not different between the LGI and HGI trials. Moreover, the participants' urine osmolality before the meal and before the LIST were not different between the LGI and HGI trials. Therefore, hydration status of the participants was similar between the trials.

The faster repeated sprint performance during the LIST was observed in the LGI trial compared to the HGI trial. This finding disagrees with the previous studies which reported no differences in sprint performance during a high intensity intermittent running between the LGI and HGI conditions (Bennett et al., 2012; Hulton et al., 2012; Little et al., 2009; Little et al., 2010). However, the previous studies only assessed sprint performance during the last 15 minutes of a 90-minute high intensity intermittent running with five 1 minute sprints (Bennett et al., 2012; Little et al., 2009; Little et al., 2010) or using 1 km trial after the 90 minutes

of intermittent exercise (Hulton et al., 2012). Therefore, the protocols employed by the previous studies did not involve multiple short sprints and this possibly explains the reason for the differences in the findings from the current and previous studies. A potential reason for the difference in repeated sprint performance between the LGI and HGI trial in the current study is that a lower relative exercise intensity during the LGI trial compared to the HGI trial. The present study demonstrated that heart rate and RPE were lower during the LGI trial compared to the HGI trial. This finding disagrees with the previous studies which reported no difference in heart rate responses and RPE between the LGI and HGI meal conditions during a high intensity intermittent running (Bennett et al., 2012; Hulton et al., 2012; Little et al., 2009; Little et al., 2010). The cause of this disagreement is unknown but the result from the current study suggests that a consumption of LGI high CHO pre-exercise meal allows participants to exercise at a lower intensity compared to a consumption of HGI high CHO pre-exercise meal during the LIST and this may have an association with the faster repeated sprint performance during the LGI trial compared to the HGI trial.

Another possible reason for the faster repeated sprint performance during the LGI trial compared to the HGI trial is that a higher plasma glucose concentration during the LIST in the LGI trial compared to the HGI trial especially prior to the start of the LIST (Hulton et al., 2012) and towards the end of the LIST (Bennett et al., 2012). Main energy sources for repeated sprints are glycolysis and phosphocreatine (PCr) which contribute to at least 90% of energy provision (Gaitanos et al., 1993) and a higher plasma glucose level may enhance rate of glycolysis and PCr resynthesis during the repeated sprints. Moreover, a higher blood glucose concentration has been shown to associate with a faster 15 m sprint speed during a soccer match simulated exercise protocol similar to the LIST (Kingsley et al., 2014). Therefore, higher availability of plasma glucose may had a link with the faster repeated sprint performance during the LIST in the LGI trial compared to the HGI trial. However, this is only an assumption as the current study did not measure plasma glucose.

The current study examined the influence of

high CHO meal with various GI on repeated sprint performance during the LIST. In soccer, sprint-type activities are widely considered as a crucial element of performance even though such activities only contribute to a small proportion of the overall motion activities during a match (~10% of the total distance covered during the matches) (Carling, Bloomfield, Nelsen, and Reilly, 2008). Moreover, sprinting occurs ~40 times per player during a soccer match that an ability to repeat short sprints has been argued as an important aspect in soccer (Carling et al., 2012). However, the original version of the LIST (Nicholas et al., 2000) did not include sprints in Part B. Moreover, a few previous studies which examined influences of high CHO pre-exercise meal with various GI on soccer match simulated high intensity intermittent running focused on either five 1 minute sprint performance in the last 15 minutes of a 90-minute high intensity intermittent running (Bennett et al., 2012; Little et al., 2009; Little et al., 2010) or 1 km running time trial performance after a 90-minute high intensity intermittent running (Hulton et al., 2012). Therefore, the current study included sprints in Part B of the LIST to examine repeated sprint performance.

The current study demonstrated that GI of high CHO pre-exercise meal does not influence time to exhaustion during the LIST. This finding was expected as GI of high CHO pre-exercise meal has been reported not to influence time trial performance towards the end or just after a 90 minute high intensity intermittent exercise (Bennett et al., 2012; Hulton et al., 2012; Little et al., 2009; Little et al., 2010).

In the current study, menstrual cycle was not controlled because it has been reported that menstrual cycle does not influence time to exhaustion and sprint performances during the LIST (Sunderland and Nevill, 2003). A study compared time to exhaustion and sprint performance during the LIST between follicular and luteal phases in well-trained female games players with a mean age of 20 years. The result revealed that menstrual cycle phase do not affect time to exhaustion or sprint performance during the LIST (Sunderland and Nevill, 2003). Hence, menstrual cycle was not considered in the present study.

For the future studies, it is advised to include data

which enable analyses of metabolism especially blood glucose concentration. Moreover, an inclusion of ball related activities in the protocol would probably make the exercise protocol even more similar to a soccer match.

5. Conclusion

The current study demonstrated a faster repeated sprint performance during the LIST after a consumption of LGI high CHO meal 3 hours before the exercise compared to a consumption of HGI high CHO meal in trained adult female soccer players. Potential rationales for the differences are that a consumption of LGI high CHO meal lowers the relative exercise intensity (heart rate) and perception of the exercise intensity (RPE) compared to a consumption of HGI meal during the same exercise. Moreover, as described in the previous studies, a higher blood glucose concentration at the start and towards the end of soccer match simulated intermittent running after a consumption of LGI high CHO meal compared to HGI high CHO meal may have a link to the key finding of the current study. Therefore, female soccer players are advised to consume a LGI high CHO meal three to four hours prior to a training session or match and such advice is possibly valid for other team sports which include high intensity intermittent running similar to soccer.

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- Japanese Society of Physical Fitness and Sports Medicine
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