The influence of carbohydrate mouth rinse on self-selected speeds during a 30 minute treadmill run

Ian Rollo, Clyde Williams, Nicholas Gant and Maria Nute

School of Sport and Exercise Sciences, Loughborough University, Loughborough, UK.

Address correspondence to: Ian Rollo

School of Sport and Exercise Sciences

Sir John Beckwith Centre for Sport

Loughborough University,

Loughborough,

LE11 3TU, UK.

telephone: +44 (0)1509 228183

fax: +44 (0)1509 226301

e-mail: I.Rollo@lboro.ac.uk

Abstract

The purpose of this study was to examine the influences of a carbohydrate (CHO) mouth rinse on self-selected running speeds during a 30-min treadmill run. Ten endurance trained males performed two trials, each involving a 10-min warm-up at 60% $\dot{V}O_2$max followed by a 30-min run. The run was performed on an automated treadmill that allowed the spontaneous selection of speeds without manual input. Participants were asked to run at speeds which equated to a Rating of Perceived Exertion (RPE) of "15", mouth rinsing either a 6% carbohydrate (CHO) or taste matched placebo (PLA) solution. In addition to recording self-selected speeds and total distance covered we also assessed the subjective feelings of the runners. The total distance covered was greater during the CHO than during the PLA trial ($P<0.05$). Faster speeds selected during the first 5-min of exercise corresponded with enhanced feelings of pleasure when mouth rinsing the CHO solution. Mouth rinsing with a CHO solution increased total distance covered during a self-selected 30-min run in comparison to mouth rinsing a colour and taste matched placebo.

Key words: *treadmill, carbohydrate, rinse*

Introduction

Prolonged exercise depletes stores of muscle glycogen (Bergstrom & Hultman, 1967). The ingestion of appropriate carbohydrate (CHO) solutions before and during exercise has been shown to delay fatigue (Bergstrom, Hermansen, Hultman, & Saltin, 1967; Coggan & Coyle, 1987; Tsintzas, Williams, Boobis, & Greenhaff, 1996) and improve exercise performance (Anantaraman, Carmines, Gaesser, & Weltman, 1995; Jeukendrup, Brouns, Wagenmakers, & Saris, 1997). The quantity of carbohydrate required to benefit exercise performance has been shown to be approximately 40-60

g/h (Ball, Headley, Vanderburgh, & Smith, 1995; Carter, Jeukendrup, Mundel, & Jones, 2003; Coyle, 1992; el-Sayed, Balmer, & Rattu, 1997; Jeukendrup et al., 1997; Millard-Stafford, Rosskopf, Snow, & Hinson, 1997). The ingestion of carbohydrate throughout prolonged exercise contributes to glucose metabolism in the muscle (Coyle, 1992). In some cases this leads to a more gradual degradation of endogenous glycogen stores throughout exercise (Tsintzas et al., 1996), but in others there is an improvement in endurance capacity without evidence of 'glycogen sparing' (Coyle, Coggan, Hemmert, & Ivy, 1986). The reasons for these difference may be associated with the type of exercise used e.g. cycling versus running, however, this may be too simplistic an idea and so further research is required (Tsintzas & Williams, 1998).

During exercise where endogenous glycogen stores are unlikely to limit performance, there does not appear to be a clear rationale for supplying additional CHO. McConell et al. (2000) found that only a small percentage (26%) of total CHO consumed actually enters the peripheral circulation during high intensity endurance exercise. In addition the ingestion of glucose had no effect on carbohydrate oxidation, muscle metabolism, or performance when exercising to fatigue at approximately 80% peak oxygen uptake (McConell, Canny, Daddo, Nance, & Snow, 2000). Nevertheless, there are studies that show that ingesting a carbohydrate solution during relatively short duration exercise tests improves performance without apparently influencing muscle metabolism (Anantaraman et al., 1995; Powers, Lawler, Dodd, Tulley, Landry, & Wheeler, 1990). For example, Jeukendrup et al. (1997) found that performance during a 1 h time-trial performance was improved when their cyclists ingested a CHO-electrolyte solution. Subsequent investigations using the same exercise protocol found that infusing glucose (60 g/h) had no influence on performance (Carter, Jeukendrup,

Mann, & Jones, 2004b). However, simply mouth rinsing a CHO solution without ingestion led to significant improvement in performance (Carter, Jeukendrup, & Jones, 2004a). The results of these and other studies have led to the suggestion that the ingestion of CHO solution, and even simply tasting a CHO solution, may exert a positive influence on the brain and central nervous system (Carter et al., 2004a).

The concept that CHO may exert a central effect is of interest because it is consistent with findings that runners 'feel better' and report lower ratings of perceived exertion while ingesting a CHO solution during prolonged running (Backhouse, Ali, Biddle, & Williams, 2007; Backhouse, Bishop, Biddle, & Williams, 2005). If there is central recognition of CHO, it is reasonable to ask whether this alters the runners` perception towards exercise and if so, whether this translates into faster self-selected running speeds. However, the performance benefits of simply 'tasting' i.e. mouth rinsing a CHO solution observed in a cycling study has not been confirmed during treadmill running. Whitham & McKinney (2007) found no difference in total distance covered or Rating of Perceived Exertion (RPE) when runners` mouth rinsed either a 6% CHO or placebo solution at 6-min intervals throughout a 45-min time-trial. One of the limitations of studies that use treadmill running to assess nutritional interventions on time-trial performance is that the treadmill speed is adjusted manually either by the runner or by the investigator. This approach does not allow runners to change their speed spontaneously according to how they 'feel' (Laursen, Francis, Abbiss, Newton, & Nosaka, 2007; Whitham & McKinney, 2007). In contrast, power output during cycling can be quickly changed simply by changing pedal cadence. Thus, cycling may be a more sensitive way of reflecting how the cyclists 'feel' during time-trials following nutritional interventions. This difference in exercise mode may explain why

the improvement in time-trial performance during cycling, as a result of mouth rinsing a CHO solution, was not confirmed during treadmill running (Carter et al., 2004a; Whitham & McKinney, 2007).

To overcome this limitation we used an automated treadmill system that allows free and spontaneous changes in running speed, without manual input. This automated system is more sensitive to the selection and alteration in running speed throughout exercise than are traditional treadmills (Whitham & McKinney, 2007). Therefore it should allow runners to change their speed according to 'how they feel'. Whilst the administration of the RPE scale (Borg, 1982) provides information on the intensity of the perceived exertion it does not help describe 'how the runners feel' during exercise (Hardy & Rejeski, 1989). Administering both a Feeling Scale (FS) and RPE scale, it is possible to measure not only "what" (RPE) but "how" (FS) a person feels (Hardy & Rejeski, 1989). In addition, whether runners' feelings are 'good or bad' (pleasure-displeasure) or feel 'energised' (i.e. an activated state) during exercise are also relevant because it is likely that may influence their performance (Acevedo, Gill, Goldfarb, & Boyer, 1996). The perceived activation scale (Felt Arousal Scale [FAS] (Svebak & Murgatroyd, 1985) has been shown to be a valid measure of participants` perception of their own bodily arousal/activation during exercise (Backhouse et al., 2007).

To this end, the aim of the present study was to investigate the influence of mouth rinsing a CHO solution and taste matched placebo solution on self-selected treadmill running speeds. In addition we wanted to determine if runners 'felt any better' while mouth rinsing the CHO solution during the 30-min run and so explore possible links

with their choice of running speeds. To help runners select the same range of treadmill speeds they were asked to select a pace that represented a rating of 15 (hard) on the Borg RPE scale (Borg, 1982).

Methods

Participants

Ten endurance trained recreational runners (23 ± 4 years; body mass 75 ± 7 kg, height 181 ± 7 cm, $\dot{V}O_2$max 62 ± 3 ml.kg^{-1}.min^{-1}) (mean ± SD) gave their written consent before participating in this study approved by Loughborough University Ethical Advisory Committee. The number of participants was determined using a nomogram based upon the ratio limits of agreement (Nevill & Atkinson, 1997). Participants were regularly running for 30-60 min, 3-5 days a week. Hence, the duration of the run in the present study was within their normal training programme.

Experimental design

Determination of maximal oxygen uptake and familiarisation with the automated treadmill was completed during the first visit to the laboratory (Taylor, Buskirk, & Henschel, 1955). The second visit involved runners becoming fully habituated with the demands of the experimental protocol. Experimental trials, visits 3 and 4 were separated by 7 days, utilising randomised double blinded cross over design.

Treadmill

All tests were carried out on a motorised treadmill (Runner MT2000, Bianchini and Draghetti, Cavezzo, Italy). The treadmill used in this study had an ultrasonic feedback-controlled radar modulator that spontaneously regulated treadmill belt speed

corresponding with the changing position of the runner on the treadmill belt (Minetti, Boldrini, Brusamolin, Zamparo, & McKee, 2003). Thus the treadmill speed increased or decreased as the runner moved to the front or the back of the treadmill belt respectively. Changes in speed were therefore achieved without the need for manual input or visual feedback to the participant. More specifically, when the runner moved to the front section of the treadmill (< 36 cm from treadmill console) the speed increased (0.8 m/s). If the runner remained in the middle (between 36 and 65 cm from treadmill console) of the treadmill, speed remained constant. When the runner moved to the rear of the treadmill (> 65 cm from treadmill console) the speed decreased (1.1 m/s). Consequently the runner was always brought back to the centre of the treadmill belt. Running speeds were logged by computer at 15-s intervals for the duration of the run.

In the 48 h period before the main trials runners were asked to consume and record their habitual diet that was similar to that which they adopted prior to preparing for a race. Runners were also asked not to consume caffeine or alcohol during this period. The same diet was repeated prior to each trial. On the morning of each trial runners reported to the laboratory following an overnight fast and sat quietly in a comfortable environment (20ºC, 55% Relative Humidity (RH)) for 30-min. After 25-min at rest, a 5-min expired air sample was collected and analysed using Douglas bag method (Tsintzas, Williams, Singh, Wilson, & Burrin, 1995). Thereafter, participants emptied their bladder before their body mass was recorded.

All tests were conducted in a laboratory maintained at 19 ± 1 °C, RH 62 ± 8%, containing only the treadmill and fan positioned 1m in front of the runner with

constant air speed to provide cooling throughout the run. Human interaction was limited to the collection of expired air samples, ratings of subjective scales and the delivery of solutions. Runners were monitored throughout exercise via closed circuit television by an investigator in an adjacent room. The treadmill display panel was covered during each trial so that runners were only able to see a clock displaying the time remaining during each phase of the run. All trials involved 40-min of treadmill running using a 1% treadmill gradient in order to simulate the energetic cost of outdoor running (Jones & Doust, 1996).

The tests comprised of a 2-min walk at 4 km/h followed by a 10-min warm-up run at a speed equivalent to 60% $\dot{V}O_{2max}$. Immediately after the 10-min warm-up run the runners began the 30-min trial. The runners were asked to select speed which they perceived to be equivalent to a "hard pace" RPE of "15" for the 30-min run and were free to adjust the speed using the automated treadmill system. On completion of 30-min run, the runners walked for a further 2-min at 4 km/h before being towel dried and their body mass recorded. Runners received no feedback about the distance covered over the 30-min run until the completion of the study.

Expired air, heart rate and ambient conditions

Expired air was collected and analysed using the Douglas bag method, substrate oxidation was subsequently determined by indirect calorimetry (Frayn, 1983). Heart rate was monitored and recorded at 5-s intervals using short range telemetry (Polar Electro, Kempele, Finland). Dry and wet bulb temperatures were measured using a whirling hygrometer (Brannan Thermometers Ltd, Cumberland).

Solution and rinse protocol

During the two main trials either a 6.0 g/100 ml carbohydrate (CHO) or a taste matched placebo (PLA) was rinsed round the oral cavity for 5-s before being expectorated into a pre-weighed plastic bag. Plastic bags were re-weighed using a electronic balance (Mettler, Toledo AB54-s, Switzerland) to help determine whether or not any of the solution had been ingested. Each mouth rinse solution (20 ± 1ºC) was administered immediately after resting expired air collection, immediately prior to and at 3-min, 6-min and 9.5-min during the warm-up run. During the 30-min run the mouth rinse was administered at 5-min intervals. Each 25 ml bolus of solution was served in a plastic syringe (Kendal monoject) a total of 10 times, equating to 250 ml bolus of solution rinsed and expectorated over the duration of the trial.

Subjective scales

The Feeling Scale (FS) (Hardy & Rejeski, 1989) was used to assess the feelings of the runners i.e. the affective dimension of pleasure-displeasure. This FS scale is an 11-point single item bipolar rating scale that ranges from - 5 to + 5. Anchors are provided at the “0” point (“neutral”) and at all odd integers, ranging from “very good” (+5) to “very bad” (-5) (Ekkedakis, Backhouse, Gray, & Lind, 2008). The perceived activation scale (FAS, (Svebak & Murgatroyd, 1985)) is a six point, single item measure of perceived activation/arousal (energised). The scale ranges from 1 to 6, with anchors at 1 (“low arousal”) and 6 (“high arousal”), and has been used in prior exercise studies (Backhouse et al., 2007; Backhouse et al., 2005; Hall, Ekkekais, & Petruzzello, 2002). Both the FS and FAS have the advantage of most other self-report scales of being easily administered during exercise. Gastrointestinal (GI) comfort was rated using a 12 point scale with anchors provided at 0 “neutral”, 4 “uncomfortable”,

8 “very uncomfortable” and 12 “painful”. The FS, FAS, together with the GI scale were administered on arrival at the laboratory, 25-min into the rest period, immediately prior to and at 3-min, 6-min and 9.30-min into the 10-min warm-up run. During the 30-min run the scales were presented to the runners every 5-min i.e. before the delivery of the solutions. The runners also completed the FS, FAS and GI scales on completion of the 30-min run and at the end of the 2-min cool-down walk.

Statistical Analysis

All data were analysed using SPSS (version 13.0). A Shapiro-Wilk test was used to normally distribute the data. The mean differences in self-selected running speed and comparisons over time (analysed in 5-min blocks over the 30-min run) were detected using a two-factor (trial x time) repeated measures analysis of variance (ANOVA) with repeated measures on both factors used to analyse for main effects and interaction of these two factors. Significant interaction between the trial and time factors in the ANOVA were explored using the Holm-Bonferroni step-wise method. For comparisons between single normally distributed data, paired Student’s t-tests and Pearson’s correlation coefficient were used to examine differences between trials. Psychological and G.I scales were analysed using a two-factor ANOVA for repeated measures on two factors (experimental condition and sampling time). Significant main effects for individual time points were further analyzed using paired t-tests and the Bonferroni adjustment for the number of pairwise comparisons was employed. All data are presented as mean ± SD. Significance alpha level was set at 0.05 to indicate statistical significance.

Results

Mean energy intake over the 48 h period prior to exercise was 10.3 ± 3.2 MJ/day. The mean mass of CHO, fat and protein consumed during the 48 h record period was 5.1 ± 1.7 g/kg BM^{-1}·day^{-1}, 1.1 ± 0.6 g/kg BM^{-1}·day^{-1} and 1.3 ± 0.4 g/kg BM^{-1}·day^{-1} respectively. No trial order effect was discovered in any variables reported.

Physiological response

There was no difference between trials in heart rate response to exercise: mean heart rate during the 10-min warm-up was 130 ± 6 beats/min for both CHO and PLA trials. Heart rates analysed at 15 s intervals in 5-min blocks, revealed a significant increase during the 30-min run ($P<0.05$). However, there were no differences between CHO and PLA trials (CHO 162 ± 7 beats/min vs. PLA 161 ± 7 beats/min, $P>0.05$). The mean loss of body mass as sweat was 0.9 ± 0.4 kg and 0.8 ± 0.2 kg for the PLA and CHO trials ($P>0.05$).

Subjective response

Rating of perceived activation (FAS) increased from rest (CHO 2.2 ± 1.0; PLA 2.7 ± 0.7) to the start of exercise ($P<0.05$). No difference was observed over the 30-min run and there were no differences between trials (CHO 3.8 ± 0.2 vs. PLA 3.6 ± 0.1, Figure 1). There were no differences in ratings of pleasure-displeasure (FS) at rest (CHO 1.1 ± 1.0 vs. PLA 1.0 ± 1.2). However, FS was elevated at the start of the 30-min run while rinsing the CHO solution (PLA: 1.3 ± 1.2 vs. CHO: 2.2 ± 0.6, $P<0.05$, Figure 2), but there were no differences between trials during the remainder of the 30-min run (CHO 1.9 ± 0.2 vs. PLA 1.6 ± 0.1, $P>0.05$). Although, there was no differences in gastrointestinal discomfort (GI) at rest (CHO 0.8 ± 1.1 vs. PLA 0.7 ± 1.1), it did

increase over the 30-min run, but with no differences between trials (CHO 1.6 ± 0.8 vs. PLA 1.5 ± 0.6, Figure 3).

Self-selected running speed

Pacing strategy during the 30-min run can be seen in Table 1. The self-selected running speed for PLA was 12.9 ± 1.3 km/h vs. 13.2 ± 1.1 km/h for the CHO trial ($P>0.05$) (Figure 4). Analysed at 15-s intervals in 5-min blocks self-selected speed was faster in the first 5-min of the 30-min run when rinsing with the CHO solution ($P<0.05$). Consequently runners covered a significantly greater distance during the first 5-min of the 30-min run (CHO 1039m vs. PLA 1016m). The total distance covered was 6469 ± 515 m during the PLA trial and 6584 ± 520 m during the CHO trial. Thus during the CHO trial the distance run was 115 m further, i.e. 1.7% of the total distance, than on the placebo trial ($P<0.05$). Post-trial interviews with the runners revealed that only two of the ten runners were able to correctly identify the solution rinsed during the tests.

Metabolism

No difference was observed in resting oxygen uptake between the two trials (VO_2: PLA = 0.30 ± 0.04 l/min, CHO = 0.31 ± 0.06 l/min) or RER (PLA = 0.89 ± 0.12, CHO= 0.87 ± 0.04). During the 10-min warm up, VO_2 and RER (PLA = 2.5 ± 0.2 l/min, 0.92 ± 0.06, CHO = 2.5 ± 0.2 l/min, 0.91 ± 0.04) were not different between the CHO and PLA trials. The quantity of solution expectorated was equal to or greater than the quantity rinsed (PLA 252.5 ± 2.4 ml vs. CHO 251.5 ± 1.7 ml, $P>0.05$).

There was no difference in estimated CHO oxidation rate during the resting period prior to exercise (CHO 0.19 ± 0.05 g/min vs. PLA 0.22 ± 0.05 g/min) or during the 10-min warm-up (CHO 2.5 ± 0.2 g/min PLA 2.5 ± 0.2 g/min). Estimated fat metabolism did not differ at rest (CHO: 0.06 ± 0.07 g/min PLA: 0.07 ± 0.02 g/min) or during the 10-min warm-up (CHO: 0.31 ± 0.23 g/min PLA: 0.43 ± 0.23 g/min). Estimated energy expenditure (kcal/kg.bm^{-1}.km^{-1}) over the duration of the 30-min run was significantly greater when rinsing with the CHO solution (CHO 493 ± 54 kcal vs. PLA 485 ± 55 kcal, $P<0.05$).

Discussion

The aim of this study was to determine whether mouth-rinsing a CHO solution influenced the self-selection of running speeds as well as possible links between the choice of speeds and how the runners 'felt' at the time. The results of the study showed that mouth rinsing with a 6% CHO solution significantly increased the self-selected speed during the first 5-min of the 30-min run. The selection of an initial faster speed resulted in a greater distance covered over the first 5-min and contributed to a significant difference in total distance covered in 30-min.

Rather than complete a set distance in the fastest time possible, we asked the runners to select a speed that equated to a "hard pace" i.e. 15 on the Borg scale (Borg, 1982) for a 30-min run. Using an automated treadmill the runners were able to spontaneously adjust their speed with no manual input, thus providing a unique insight into how a CHO mouth rinse influenced self-selected running speed. However, we acknowledge that runners` interpretation of an RPE of "15" (hard) would undoubtedly be influenced by the run duration. Therefore, we informed runners of the

specific run time i.e. 30-min and provided them with the time remaining during the run.

The results of the present study provide some support for the findings of Carter et al. (2004a), who reported that mouth rinsing a 6.4% maltodextrin solution improved 1-h cycle time-trial performance. In their study, the cyclists were able to maintain a higher power output for the first 75% of the time-trial while mouth-rinsing the CHO solution. In addition, they completed the time-trial while recording the same ratings of perceived exertion as in the placebo trial, even though they were exercising at a higher power output. Similarly, in the present study we found that despite being asked to run at the same perceived exertion, runners selected faster running speeds when mouth rinsing the CHO solution. However, in contrast to Carter et al. (2004a) this difference only reached statistical significance over the first 5-min of exercise (Table 1). After 5-min the effect of the CHO mouth rinse appeared to diminish with time (Figure 4).

In contrast to the results of the present study, Whitham & McKinney (2007) recently reported that mouth rinsing a CHO solution had no effect on 45-min running performance, using a traditional treadmill. Runners completed a warm-up run at 65% of $\dot{V}O_{2max}$ before being asked to run as far as possible in 45-min. Runners mouth-rinsed either a 6% maltodextrin or placebo solution before and during the time-trial. However, no difference in running speed or perceived exertion was reported at any time point during the trials. It is unclear why the findings of the present study differ from those of this recent study. Direct comparisons are difficult, as the present study was not a 'time-trial' per se. Whitham & McKinney (2007) used a traditional treadmill that required manual changes in speed whereas in the present study the

automated treadmill changed speed as the runners increased or decreased their pace. Studies in which runners change the treadmill speeds manually may not have the same degree of sensitivity to nutritional interventions as is the case when using an automated treadmill (Whitham & McKinney, 2007). Thus, manually changing the speed may not be sufficient to detect any subtle effects that CHO mouth rinse may impact on the runners (Laursen et al., 2007; Whitham & McKinney, 2007). Furthermore, in the mouth-rinse study that used a manually controlled treadmill, speeds were recorded at 5-min intervals (Whitham & McKinney, 2007). In the present study treadmill speeds were recording every 15-s which provided a better description of the runners' responses to the mouth rinse solutions. Alternatively, as seen in the present study, the major effect of mouth rinsing CHO is observed at the beginning of exercise and as previously mentioned diminished with time. Thus, as the exercise duration increases, the likelihood of reporting a significant difference in distance run will decrease. Though this does not support the results reported for cycling by Carter et al., 2004a this may explain why Whitham & McKinney, (2007) found that mouth rinsing a carbohydrate solution had no effect on the distance covered during 45-min of treadmill running.

Possible placebo effects may have large influences when investigating small changes in exercise performance (Clark, Hopkins, Hawley, & Burke, 2000). Despite being colourless and non-sweet, Carter et al. (2004a) reported that 4 of their 9 subjects were able to identify the mouth rinse carbohydrate solution. Whitham & McKinney (2007) resolved this potential problem by adding bitter lemon juice to the maltodextrin and placebo solutions, resulting in only 1 of the 7 runners identifying the CHO solution. In the present study only 2 of the ten runners were able to distinguish between an orange

flavoured 6% glucose solution and a colour, viscosity and tasted matched placebo. Although the carbohydrate solution differed from maltodextrin used in previous mouth rinse studies (Carter et al., 2004a; Whitham & McKinney, 2007) the solutions were suitably indistinguishable without the addition of any potentially undesirable masking agents.

Interestingly all runners increased their running speed during the final 15-min of the 30-min run. This finding is consistent with both laboratory (Palmer, Borghouts, Noakes, & Hawley, 1999; Rauch, St Clair Gibson, Lambert, & Noakes, 2005; Weltan, Bosch, Dennis, & Noakes, 1998a, 1998b) and field (Billat, Slawinski, Danel, & Koralsztein, 2001; Sandals, Wood, Draper, & James, 2006) studies that observe an increase in speed over the final stages of exercise. However, the observed increase in speed towards the end of the 30-min run was unexpected because the runners were asked to maintain the same perceived exertion for the duration of the run. The increases in speed were not accompanied with improved perceived activation or pleasure-displeasure that might be expected when nearing the completion of a run. Therefore it would be of interest to determine how the selection of speed and psychological response may change when the duration of the run is blinded. In this case, no increases of speed would be expected as the runner would not know when they were nearing completion of the exercise. Nevertheless, in the present study blinding runners to the exercise duration would have prevented them from repeating their perceived effort to the exercise task. This is supported by our findings that the pattern of energy expenditure during the 30-min run did not change greatly between trials or runners (Figure 4, (Foster, De Koning, Hettinga, Lampen, La Clair, Dodge, Bobbert, & Porcari, 2003)). However, the amplitude of positive changes in running

speeds were greater when mouth rinsing with the CHO solution, i.e. 0.3 km/h faster over the 30-min (Figure 5).

How runners select a speed for a given duration or distance remains an unanswered question. It has been suggested that during exercise athletes use a monitoring process that allow them to complete a prescribed distance before exhausting their available sources of energy/fuel (Foster et al., 2003). The subjective evaluations of ones condition that is "how you feel" has been described as interoception (Craig, 2002). Therefore during exercise interoception maybe be involved in, for example, the selection of running speeds. Interoception functions through the lamina I spinothalamocortical system and acts as a homeostatic afferent pathway that conveys signals from small diameter primary afferents that represent the physiological status of all tissues of the body. These feelings have not only a sensory, but also an affective, motivational aspect (Craig, 2002). In the present study, administering both the FS and FAS scale, enabled a more complete description and examination of the subjective experience following mouth rinsing a CHO solution. The ingestion of CHO has been reported to elevate perceived activation during the final 30-min of 120-min intermittent running exercise (Backhouse et al., 2007) and also attenuate the decline in pleasure-displeasure during a 120-min bout of cycling (Backhouse et al., 2005). To our knowledge, no findings relating to these scales have been reported during shorter duration exercise. In the present study, there was a trend for runners to experience higher perceived activation whilst mouth rinsing with the CHO solution but failed to reach statistical significance. Interestingly, the observation of an enhanced feeling of pleasure at the onset of the 30-min run when rinsing with the CHO solution, corresponded to the significant increase in speed over the first 5-min. These findings,

taken together with those of Backhouse et al. (2005, 2007) suggest that the ingestion or recognition of CHO in the mouth may induce a "feel good" effect.

Speculatively, the brain or lamina I spinothalamocortical system may be monitoring the physiological integrity of the muscle and/or whole body CHO stores. Recognition of CHO in the mouth may relay signals of an incoming energy source to the brain. This 'promise' of additional CHO may generate an altered response towards exercise, e.g. the selection of faster running speeds in the first 5-min of the run, as in the present study. Subsequently, when the brain receives feedback that no energy source has arrived, exercise behaviour maybe adjusted accordingly (Figure 4). Similarly, the "promise" of additional CHO may induce an altered psychological response towards exercise, e.g. runners experiencing enhanced feelings of pleasure at the onset of exercise. When the brain receives feedback that no energy source has arrived, mood state is adjusted accordingly (Figure 2). This may explain why no significant differences in perceived activation or pleasure/displeasure are observed during exercise in present study but have been reported with CHO ingestion during prolonged exercise wherein the "promise" of CHO delivery has been met, i.e. the CHO solution was ingested (Backhouse et al., 2007; Backhouse et al., 2005).

In summary, mouth-rinsing a 6% CHO solution significantly altered the initial self-selected speed during the first 5-min of a 30-min run at a set rating of perceived exertion. The increase in speed corresponded with runners experiencing elevated feelings of pleasure at the onset of the exercise task. The precise mechanisms responsible for the link between the positive feelings induced by mouth rinsing with CHO and the selection of faster running speed remain to be determined.

REFERENCES

Acevedo, E., Gill, D., Goldfarb, A., & Boyer, B. (1996). Affect and perceived exertion during a two-hour run *International Journal of Sport Psychology, 27*, 286-292.

Anantaraman, R., Carmines, A. A., Gaesser, G. A., & Weltman, A. (1995). Effects of carbohydrate supplementation on performance during 1 hour of high-intensity exercise. *International Journal of Sports Medicine, 16*(7), 461-465.

Backhouse, S. H., Ali, A., Biddle, S. J., & Williams, C. (2007). Carbohydrate ingestion during prolonged high-intensity intermittent exercise: Impact on affect and perceived exertion. *Scandinavian Journal of Medicine & Science in Sports, 17*(5), 605-610.

Backhouse, S. H., Bishop, N. C., Biddle, S. J., & Williams, C. (2005). Effect of carbohydrate and prolonged exercise on affect and perceived exertion. *Medicine and Science in Sports and Exercise, 37*(10), 1768-1773.

Ball, T. C., Headley, S. A., Vanderburgh, P. M., & Smith, J. C. (1995). Periodic carbohydrate replacement during 50 min of high-intensity cycling improves subsequent sprint performance. *International Journal of Sport Nutrition, 5*(2), 151-158.

Bergstrom, J., Hermansen, L., Hultman, E., & Saltin, B. (1967). Diet, muscle glycogen and physical performance. *Acta Physiologica Scandivica, 71*(2), 140-150.

Bergstrom, J., & Hultman, E. (1967). A study of the glycogen metabolism during exercise in man. *Scandinavian Journal of Clinical and Laboratory Investigation, 19*(3), 218-228.

Billat, V. L., Slawinski, J., Danel, M., & Koralsztein, J. P. (2001). Effect of free versus constant pace on performance and oxygen kinetics in running. *Medicine and Science in Sports and Exercise, 33*(12), 2082-2088.

Borg, G. (1982). Ratings of perceived exertion and heart rates during short-term cycle exercise and their use in a new cycling strength test. *International Journal of Sports Medicine, 3*(3), 153-158.

Carter, J., Jeukendrup, A. E., Mundel, T., & Jones, D. A. (2003). Carbohydrate supplementation improves moderate and high-intensity exercise in the heat. *Pflugers Archive, 446*(2), 211-219.

Carter, J. M., Jeukendrup, A. E., & Jones, D. A. (2004a). The effect of carbohydrate mouth rinse on 1-h cycle time trial performance. *Medicine and Science in Sports and Exercise, 36*(12), 2107-2111.

Carter, J. M., Jeukendrup, A. E., Mann, C. H., & Jones, D. A. (2004b). The effect of glucose infusion on glucose kinetics during a 1-h time trial. *Medicine and Science in Sports and Exercise, 36*(9), 1543-1550.

Clark, V. R., Hopkins, W. G., Hawley, J. A., & Burke, L. M. (2000). Placebo effect of carbohydrate feedings during a 40-km cycling time trial. *Medicine and Science in Sports and Exercise, 32*(9), 1642-1647.

Coggan, A. R., & Coyle, E. F. (1987). Reversal of fatigue during prolonged exercise by carbohydrate infusion or ingestion. *Journal of Applied Physiology, 63*(6), 2388-2395.

Coyle, E. F. (1992). Carbohydrate supplementation during exercise. *The Journal of Nutrition, 122*(3 Suppl), 788-795.

Coyle, E. F., Coggan, A. R., Hemmert, M. K., & Ivy, J. L. (1986). Muscle glycogen utilization during prolonged strenuous exercise when fed carbohydrate. *Journal of Applied Physiology, 61*(1), 165-172.

Craig, A. D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nature Reviews, 3*(8), 655-666.

Ekkedakis, P., Backhouse, S., Gray, C., & Lind, E. (2008). Walking is popular among adults but is it pleasant? A framework for carifying the link between walking and affect as illustrated by two studies. *Psychology of Sport and Exercise, 9*, 246-264.

el-Sayed, M. S., Balmer, J., & Rattu, A. J. (1997). Carbohydrate ingestion improves endurance performance during a 1 h simulated cycling time trial. *Journal of Sports Sciences, 15*(2), 223-230.

Foster, C., De Koning, J. J., Hettinga, F., Lampen, J., La Clair, K. L., Dodge, C., et al. (2003). Pattern of energy expenditure during simulated competition. *Medicine and Science in Sports and Exercise, 35*(5), 826-831.

Frayn, K. N. (1983). Calculation of substrate oxidation rates in vivo from gaseous exchange. *Journal of Applied Physiology, 55*(2), 628-634.

Hall, E., E,, Ekkekais, P., & Petruzzello, S., J, . (2002). The affective beneficence of vigorus exercise revisited. *British Journal of Health Psychology, 7*(47-66).

Hardy, C., J , & Rejeski, W. (1989). Not what, but how ones feels: The measurement of affect during exercise. *Journal of Sport and Exercise Psychology, 11*, 304-317.

Jeukendrup, A., Brouns, F., Wagenmakers, A. J., & Saris, W. H. (1997). Carbohydrate-electrolyte feedings improve 1 h time trial cycling performance. *International Journal of Sports Medicine, 18*(2), 125-129.

Jones, A. M., & Doust, J. H. (1996). A 1% treadmill grade most accurately reflects the energetic cost of outdoor running. *Journal of Sports Sciences., 14*(4), 321-327.

Laursen, P. B., Francis, G. T., Abbiss, C. R., Newton, M. J., & Nosaka, K. (2007). Reliability of time-to-exhaustion versus time-trial running tests in runners. *Medicine and Science in Sports and Exercise, 39*(8), 1374-1379.

McConell, G. K., Canny, B. J., Daddo, M. C., Nance, M. J., & Snow, R. J. (2000). Effect of carbohydrate ingestion on glucose kinetics and muscle metabolism during intense endurance exercise. *Journal of Applied Physiology, 89*(5), 1690-1698.

Millard-Stafford, M., Rosskopf, L. B., Snow, T. K., & Hinson, B. T. (1997). Water versus carbohydrate-electrolyte ingestion before and during a 15-km run in the heat. *International Journal of Sport Nutrition, 7*(1), 26-38.

Minetti, A. E., Boldrini, L., Brusamolin, L., Zamparo, P., & McKee, T. (2003). A feedback-controlled treadmill (treadmill-on-demand) and the spontaneous speed of walking and running in humans. *Journal of Applied Physiology, 95*(2), 838-843.

Nevill, A. M., & Atkinson, G. (1997). Assessing agreement between measurements recorded on a ratio scale in sports medicine and sports science. *British Journal of Sports Medicine, 31*(4), 314-318.

Palmer, G. S., Borghouts, L. B., Noakes, T. D., & Hawley, J. A. (1999). Metabolic and performance responses to constant-load vs. Variable-intensity exercise in trained cyclists. *Journal of Applied Physiology, 87*(3), 1186-1196.

Powers, S. K., Lawler, J., Dodd, S., Tulley, R., Landry, G., & Wheeler, K. (1990). Fluid replacement drinks during high intensity exercise: Effects on minimizing

exercise-induced disturbances in homeostasis. *European Journal of Applied Physiology and Occupational Physiology, 60*(1), 54-60.

Rauch, H. G., St Clair Gibson, A., Lambert, E. V., & Noakes, T. D. (2005). A signalling role for muscle glycogen in the regulation of pace during prolonged exercise. *British Journal of Sports Medicine, 39*(1), 34-38.

Sandals, L. E., Wood, D. M., Draper, S. B., & James, D. V. (2006). Influence of pacing strategy on oxygen uptake during treadmill middle-distance running. *International Journal of Sports Medicine, 27*(1), 37-42.

Svebak, S., & Murgatroyd, S. (1985). Metamotivational dominance: A multimethod validation of reversal theory constructs. *Journal of Personal and Social Psychology, 48*, 107-116.

Taylor, H. L., Buskirk, E., & Henschel, A. (1955). Maximal oxygen intake as an objective measure of cardio-respiratory performance. *Journal of Applied Physiology, 8*(1), 73-80.

Tsintzas, K., & Williams, C. (1998). Human muscle glycogen metabolism during exercise. Effect of carbohydrate supplementation. *Sports Medicine (Auckland, N.Z, 25*(1), 7-23.

Tsintzas, O. K., Williams, C., Boobis, L., & Greenhaff, P. (1996). Carbohydrate ingestion and single muscle fiber glycogen metabolism during prolonged running in men. *Journal of Applied Physiology, 81*(2), 801-809.

Tsintzas, O. K., Williams, C., Singh, R., Wilson, W., & Burrin, J. (1995). Influence of carbohydrate-electrolyte drinks on marathon running performance. *European Journal of Applied Physiology and Occupational Physiology, 70*(2), 154-160.

Weltan, S. M., Bosch, A. N., Dennis, S. C., & Noakes, T. D. (1998a). Influence of muscle glycogen content on metabolic regulation. *The American Journal of Physiology, 274*(1 Pt 1), E72-82.

Weltan, S. M., Bosch, A. N., Dennis, S. C., & Noakes, T. D. (1998b). Preexercise muscle glycogen content affects metabolism during exercise despite maintenance of hyperglycemia. *The American Journal of Physiology, 274*(1 Pt 1), E83-88.

Whitham, M., & McKinney, J. (2007). Effect of a carbohydrate mouthwash on running time-trial performance. *Journal of Sports Sciences, 25*(12), 1385-1392.

Figure captions

Figure 1 Perceived activation, felt arousal scale (FAS) (mean± SD) during the CHO and PLA trials. -10 to 0 = warm up at 60 % $\dot{V}O_2$max. 1 = low activation, 6 = high activation.

Figure 2 Pleasure-displeasure, feeling scale (FS) (Mean ± SD) during the CHO and PLA trials. -10 to 0 = 10 minute warm up at 60 % $\dot{V}O_2$max. Pleasure-Displeasure scale ranges from +5 very good to -5 very bad. * denotes a significant difference $P<0.05$.

Figure 3 Gastrointestinal comfort during the CHO and PLA trials. -10 to 0 = 10 minute warm up at 60 % $\dot{V}O_2$max. 0 = neutral, 4 = uncomfortable, 8 = very uncomfortable, 12 = painful.

Figure 4 Mean running speed (km/h) for the CHO and PLA trials during the 30-min performance test. For clarity (SD) is shown on separate ordinate. Mean running speed (km/h) for PLA = 12.9 ± 1.3 km/h vs. 13.2 ± 1.1 km/h for CHO. * denotes significant difference in speed analysed in 5-min blocks ($P<0.05$).

Figure 5 Mean difference in running speed (km/h) between the CHO (Line) and PLA (0) trials during the 30-min performance test. Mean running speed (km/h) for PLA = 12.9 ± 1.3 km/h vs. 13.2 ± 1.1 km/h for CHO ($P>0.05$).

Table Captions

Table 1 Mean performance variables for the CHO and PLA trials. Table reports mean ± SD for running speed (km/h) and distance covered (m). * denotes significant difference (P<0.05) in running speed over time. † denotes a significant difference in between treatments.

Table 1

		30-min Performance Test					
		0-5	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**
Running speed (km/h)	CHO	12.5 ±0.9*†	12.9 ± 0.9*	13.1 ± 1.0	13.2 ± 1.2*	13.6 ± 1.3*	13.9 ± 1.5*
	PLA	12.1 ± 1.1*	12.6 ± 1.0*	12.8 ± 1.1	13.0 ± 1.3	13.4 ± 1.4*	13.7 ± 1.6*
Distance covered (m)	CHO	1039*†	1075*	1091	1101*	1124*	1152*
	PLA	1016*	1052*	1069	1085*	1102*	1124*

Figure 1

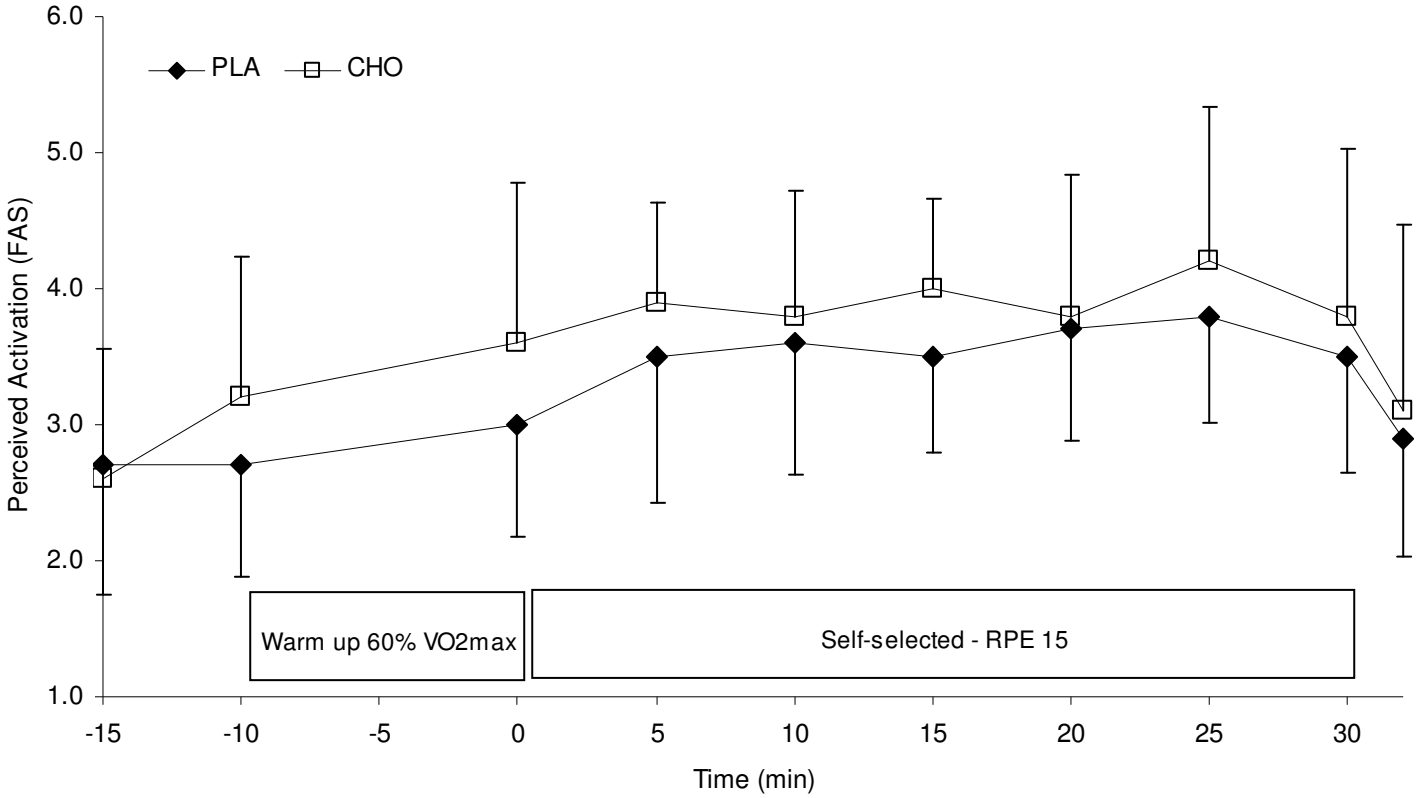

PLA
CHO
Perceived Activation (FAS)
6.0
5.0
4.0
3.0
2.0
1.0
Warm up 60% VO2max
Self-selected - RPE 15
-15
-10
-5
0
5
10
15
20
25
30
Time (min)

Figure 2

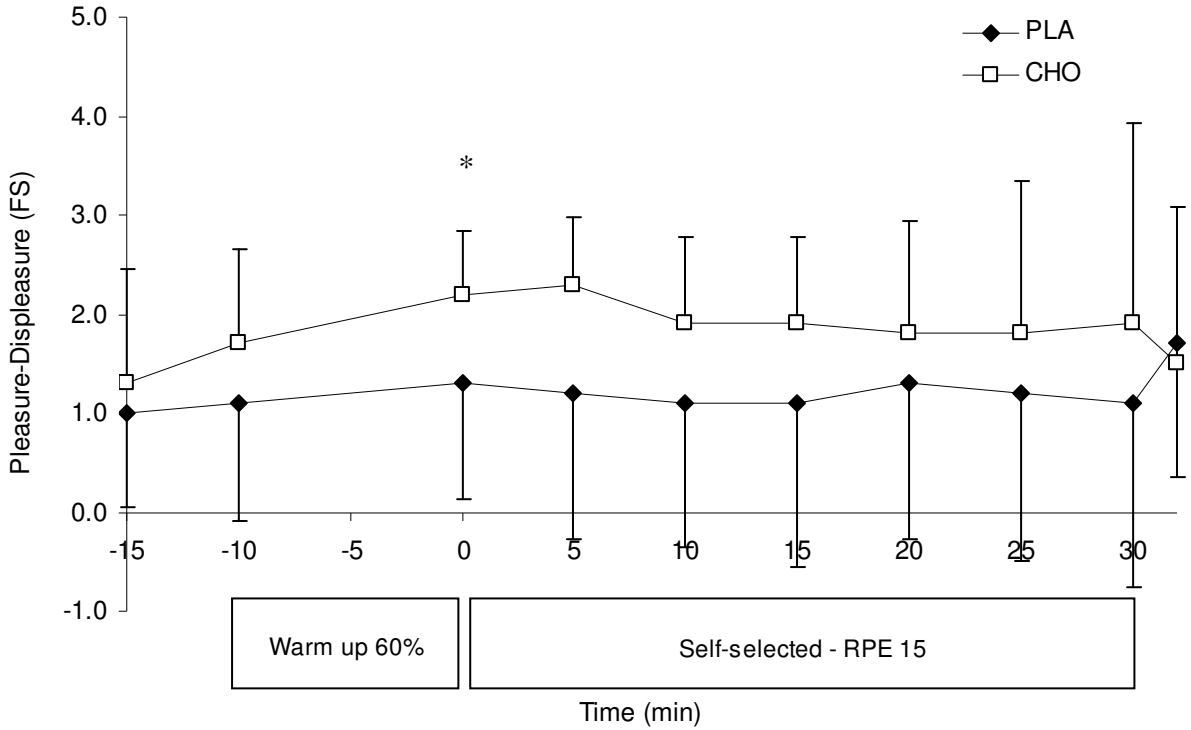

PLA
CHO
Pleasure-Displeasure (FS)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
*
-15
-10
-5
0
5
10
15
20
25
30
Warm up 60%
Self-selected - RPE 15
Time (min)

Figure 3

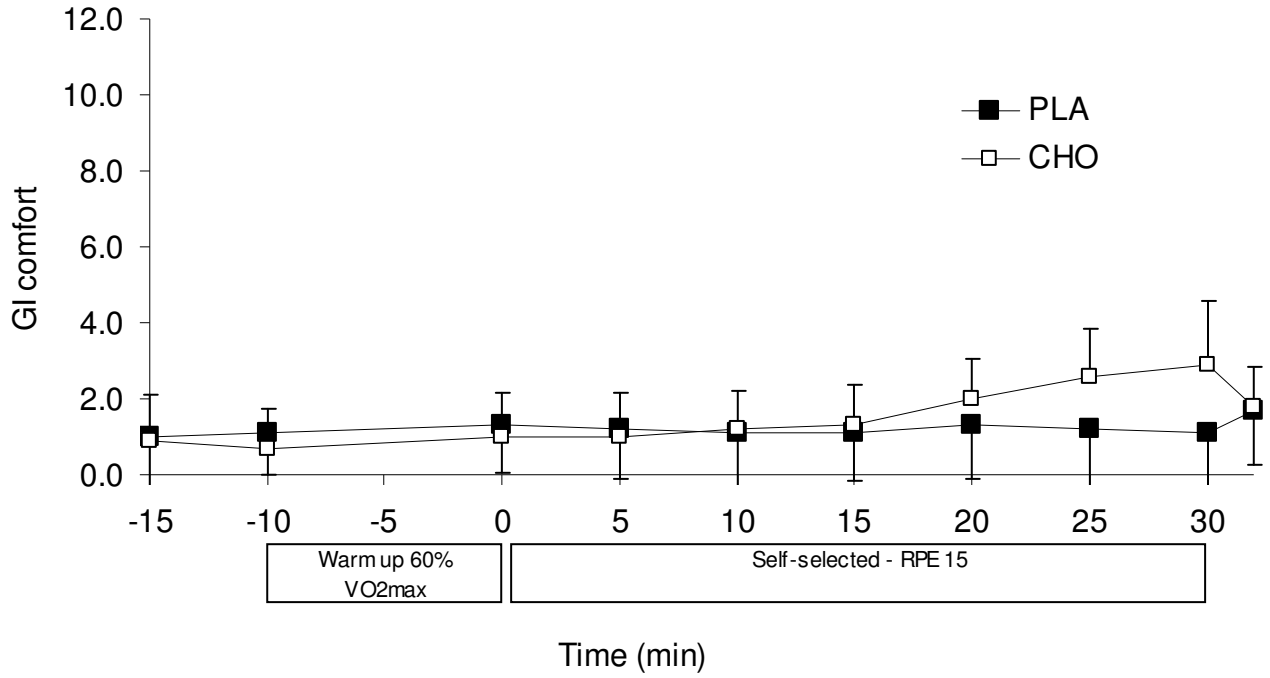

12.0
10.0
8.0
6.0
4.0
2.0
0.0
GI comfort
PLA
CHO
-15
-10
-5
0
5
10
15
20
25
30
Warm up 60% VO2max
Self-selected - RPE 15
Time (min)

Figure 4

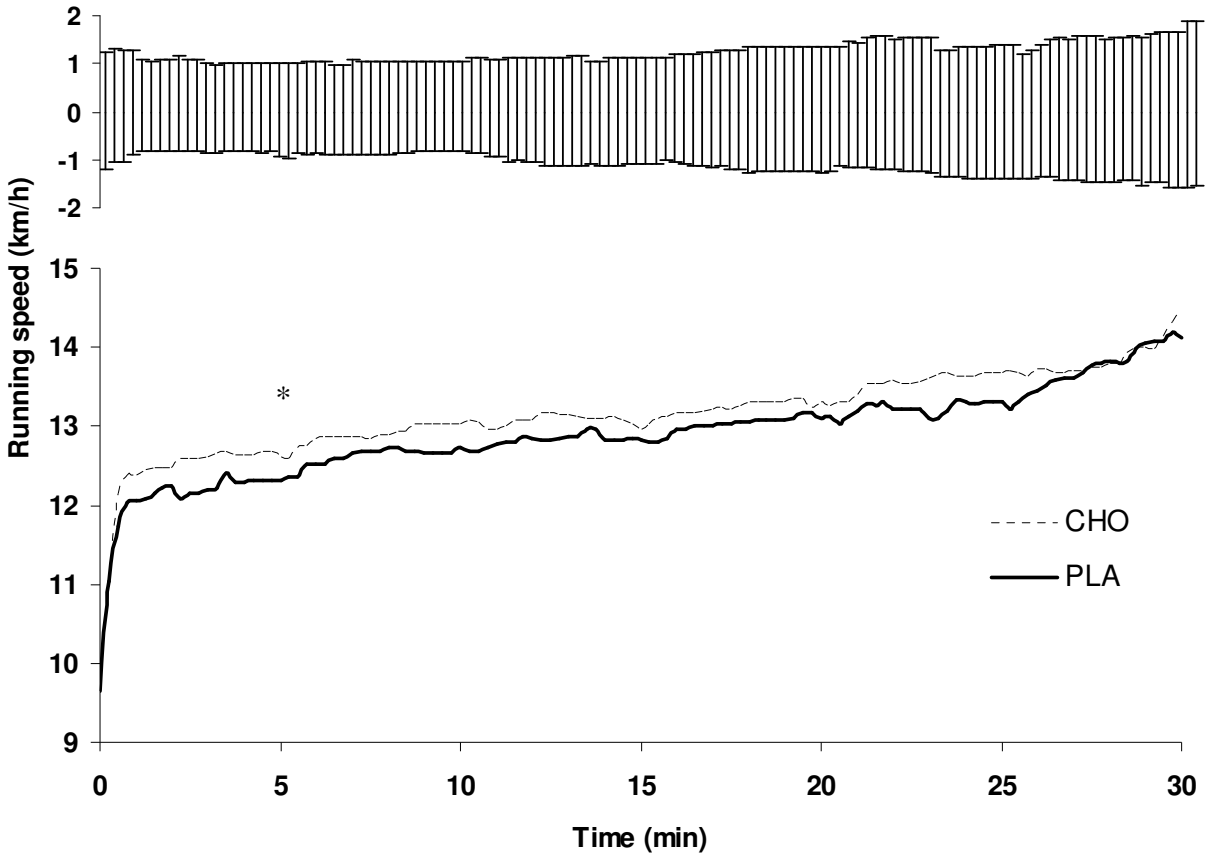
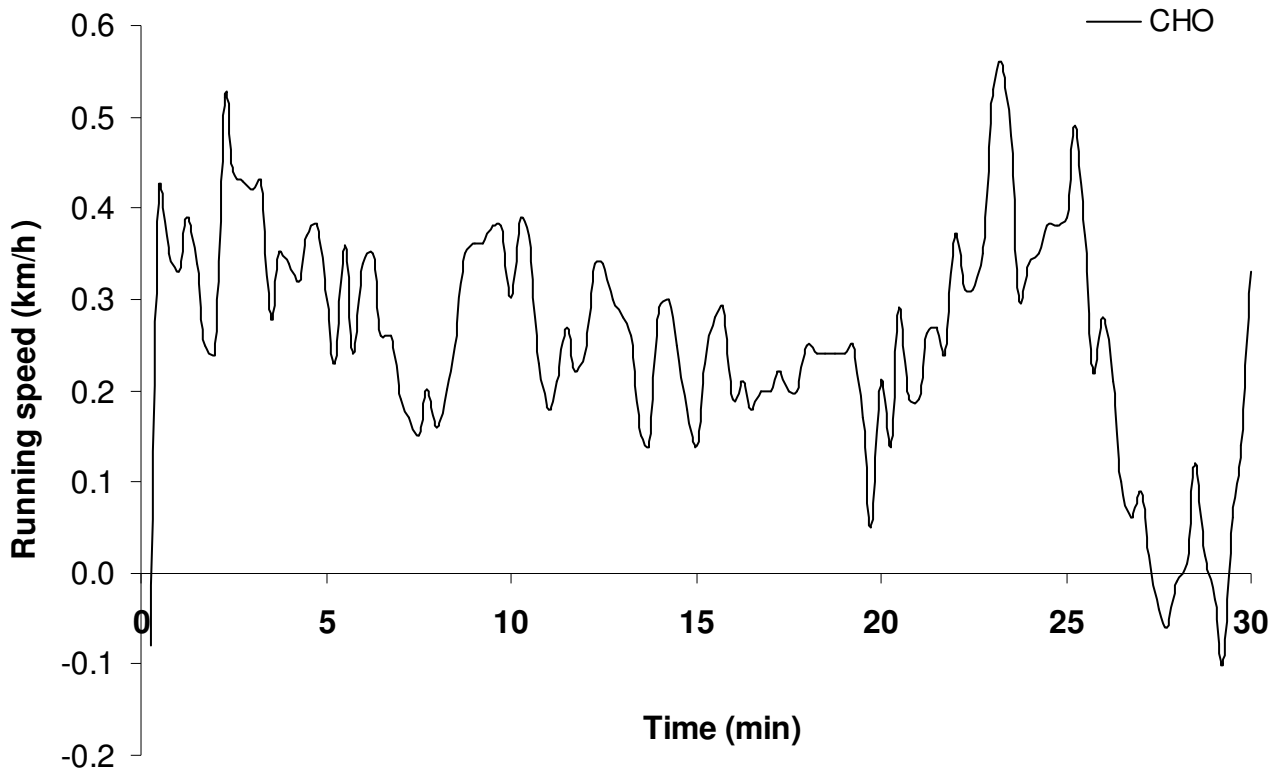

2
1
0
-1
-2
15
14
13
12
11
10
9
Running speed (km/h)
*
CHO
PLA
0
5
10
15
20
25
30
Time (min)

Figure 5


CHO
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
Running speed (km/h)
0
5
10
15
20
25
30
Time (min)