Original Article

Effects of coconut sport gel on hydration measures, cognitive performance and anaerobic capacity in soccer players: A double-blind, randomised, cross-over study

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Abstract

Purpose: This study examined the effects of coconut sports gel (CSG) on hydration measures, cognitive performance and anaerobic capacity in soccer players.

Materials and Methods: Seven soccer players (age: 21 ± 1.6 years; body weight (BW): 63.2 ± 6.6 kg; height: 172.3 ± 6.0 cm; $VO_{2\ max}$: 52.8 ± 1.4 ml. kg. min^{-1}) participated in this study. Participants underwent one preliminary testing and two experimental trials: CSG and placebo (PLA) separated at least 7 days apart. Each trial consisted of hydration measurements and two cognitive (concentration and reaction time [RT]) and anaerobic capacity (vertical jump [VJ] and repeated sprint ability [RSA]) tests at (i) baseline, (ii) dehydration and (iii) rehydration. A 90-min exercise-induced dehydration protocol was used to induce ~ 2.0% of BW loss after baseline testing. Participants were required to ingest either CSG (CHO: 26 g, K+: 381 mg) or PLA (CHO: 26 g, K+: 0 mg) at 1.2 g. kg^{-1} BW of CHO within 30 min in a randomised order and replenished plain water (100% BW loss) during the 120 min of recovery period.

Results: The results showed that participants were rehydrated after 2 h of recovery. Participants regained their BW from dehydration to rehydration: 61.3 ± 6.5 kg to 62.7 ± 6.6 kg (CSG trial) ($p < 0.001$) and 61.4 ± 6.3 kg to 62.6 ± 6.4 kg (PLA trial) ($p = 0.001$). Urine-specific gravity reduced from dehydration to rehydration: 1.0168 ± 0.0073–1.0082 ± 0.0068 ($p = 0.019$) and 1.0148 ± 0.0061–1.0108 ± 0.0054 ($p = 0.286$) in CSG and PLA trials, respectively. VJ and RSA performance were similar between trials and among time points ($p > 0.05$). The concentration scores, simple and choice RT tests showed no statistically significant difference in all time points between trials ($p > 0.05$).

Conclusion: Cognitive performance and anaerobic capacity in soccer players were well maintained after rehydration. Therefore, CSG could be an alternative option for athletes for rehydration purposes.

Key Words: Concentration, dehydration, reaction time, repeated sprint ability, vertical jump

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INTRODUCTION

Failing to maintain fluid balance will lead to hypohydration or dehydration conditions that bring detrimental effects on sport performance of the athlete that impacts the outcome of the game (Nuccio et al. 2017). Therefore, one of the most important aspects of sustaining endurance exercise performance for the duration

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soccer players is required to perform is hydration. Furthermore, sweat rates tend to increase even more when exercise is executed in hot and humid conditions (Che Muhamed et al. 2016; 2019). According to the Malaysian Meteorological Department (https://www.met.gov.my/), the average maximum ambient temperature in Malaysia is around 33°C and an average humidity of 80%. Thus, higher possibilities of progressive dehydration take place when inadequate fluid replacement occur in such conditions and tends to cause a soccer player to lose up to 3%–5% of their body weight (BW) (Baker et al. 2015; Corte de Araujo et al. 2012; Perez et al. 2018). In general, exercise performance decreases as soon as the athlete achieves more than 2% BW loss (Cheuvront and Kenefick 2014).

In addition, the overall effects of hypohydration are observed in team sports caused by the negative effects of fluid deficit on mental skills and attention focus (Burke 2007). When fluids are not replenished regularly, a decrease in blood and plasma volume makes it harder for the cardiovascular system to circulate blood, especially to the brain and working muscles which further contributes to complications such as dizziness, fatigue and other physical signs (Fortes et al. 2018; Hodges 2012; Irwin et al. 2018) one of the main factors that determines the outcome of the game other than any simple effects of muscular work output. Moreover, electrolytes such as chloride, potassium and sodium are excreted through sweating which are also minerals that are utilised to carry electrical impulses that are signals sent to the brain from the receptors and vice versa (Carlsohn et al. 2020). When there is a decline in potassium content in the cells, it compromises the neuromuscular system and affects sports performance.

Coconut water (CW) has been referred to as a natural alternative hydration beverage as compared to electrolyte sport drinks in the market. It has become a popular dehydration remedy due to its natural occurring electrolyte content such as potassium and sodium as well as carbohydrate (CHO) (Marapana et al. 2017; Perez-Idarraga and Aragon-Vargas 2014; Tan et al. 2014). CW is an ideal choice of fluid replenisher because it is a hypotonic beverage (Campbell-Falck et al. 2000), as stated by Gisolfi et al. (2001), who believe that sport beverages should be hypotonic or isotonic for quick gastric emptying and absorption. Moreover, sports drinks are made of isotonic or slightly hypotonic solutions with an osmolality range of 200–330 mOsm. kg^{-1} Marapana et al. (2017) and CW osmolality is at 228 mOsm. L^{-1} which support the previous statement. Furthermore, the electrolyte concentration in CW produces an osmotic pressure equal to that found in blood, as well as a specific gravity of approximately 1.020, which is comparable to blood plasma (Fernandes et al. 2000). As a result, in remote areas, CW has been utilised as a short-term emergency intravenous hydration substitute (Campbell-Falck et al. 2000).

Following a dehydration protocol examined by Laitano et al. (2014), it was demonstrated that CW had a beneficial influence on hydration status, and the researchers also claimed that CW intake had a superior fluid retention potential. Previous studies have suggested the ergogenic effect of CW rehydration due to its high potassium electrolyte content (Ismail et al. 2007; Laitano et al. 2014; Perez-Idarraga and Aragon-Vargas 2014; Saat et al. 2002). However, these findings remain inconclusive as there are numerous other studies that have shown no significant improvement in endurance exercise performance with ingestion of CW (Ismail et al. 2007; Peart et al. 2017; Perez-Idarraga and Aragon-Vargas 2014).

To provide competitive advantage to hypohydrated athletes, CHO sport drinks are developed to meet this demand. Recently, hydrogel (a semi solid nature of the CHO-containing gel), which claims to be able to provide greater benefits to exercising athletes. It enables a smoother transportation of a high dose of CHO through the stomach to the intestine, especially during exercise without gastrointestinal distress (Baur and Saunders 2021). Most of these commercial sport drinks and hydrogel contain mainly maltodextrin and sugars. Hence, in this present study, a coconut-based sports gel was developed utilising both the flesh and water that contains CHO and electrolyte potassium (K^+) with the idea to produce a sports gel as a natural substitute compared to synthetic sports gel. Coconut kernels contain a high percentage of short and medium chain fatty acids that can be easily metabolized to yield energy while CW is rich in minerals that replenish electrolytes loss during exercise. Therefore, this study examined the effects of coconut sports gel (CSG) on hydration measures, cognitive performance and anaerobic capacity in soccer players.

MATERIALS AND METHODS

Participants

A total of 7 soccer players were recruited in this study (n = 7) soccer players (age: 21 ± 1.6 years; BW: 63.2 ± 6.6 kg; height: 172.3 ± 6.0 cm; $VO_{2\ max}$: 52.8 ± 1.4 ml. kg. min^{-1}). Participants who participated were those who were willing to hold their on-going consumption of nutritional supplementation for at least 2 weeks before this study until they completed all the experimental trials. Subjects were advised to continue their usual diet and training regime throughout the study, unless otherwise told not to perform any strenuous exercise 24 h or fast for 8 h prior to testing. The study protocol was reviewed and approved by Tunku Abdul Rahman University College Ethics Committee (FOAS/EC/2019/1–12) [Figure 1].

Preparation of coconut sport gel and placebo

The preparation of CSG and placebo (PLA) is based on an inhouse method, with the mixture of young coconut: Mature coconut at a ratio of 1:1 [Table 1]. For CSG, coconut flesh and CW (ratio 16:5) were blended. Minor components maltodextrin, sucrose, whey protein, pectin, and cocoa powder were premixed and added into the mixture. The mixture was homogenized at 7500 rpm for 20 min. After homogenization, the mixture was filtered into a pot and pasteurized at 90°C for 2 s with continuous stirring forming a gel consistency. The gel was then placed in an ice water bath for rapid cooling before keeping in the refrigerator. For PLA, CW was replaced with an equal amount of distilled water. The density of the CSG is assumed to be like

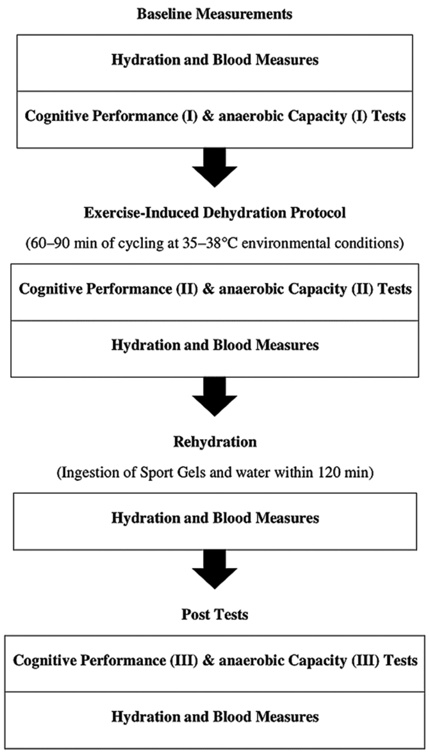

Figure 1: Flow diagram of experimental protocol

the density of yogurt at approximately 1.04 g. ml^{-1} since they are of the same consistency. Therefore, it is assumed that 1 g of gel is equivalent to 1 ml of gel.

Preliminary testing

Prior to the tests, subjects were informed about the risks, procedures and benefits of the study and consent was obtained. A maximal oxygen uptake ($VO_{2\ max}$) test was conducted to measure aerobic capacity to ensure that all the subjects recruited were fit and meet the inclusion criteria of at least 50 ml. kg^{-1}.min^{-1}. Subjects performed the $VO_{2\ max}$ test on a motorised treadmill (H/P/Cosmos Quasar, Germany) and the expired gas was analysed by true one 2400 metabolic cart (ParvoMedics, Sandy, UT). The test began with a submaximal test where subjects started at their individualised speeds based on their 10-km timings and at every 4-min stage, the speed increased 1.5 km. hr^{-1} for 4 stages. Next, subjects were rested for 20 min before beginning the $VO_{2\ max}$ test. During the $VO_{2\ max}$ test, subjects ran at constant speed throughout the test with the treadmill's gradient increasing 2% at every 2 min and continued until voluntary exhaustion with at least three $VO_{2\ max}$ criteria were met.

Subjects were reminded to avoid any supplementation, refrain from performing any physical activity and alcoholic beverages for at least 24 h before each experimental trial. Moreover, they were told to stop any food intake for overnight at least 8 h before testing but were encouraged to maintain water intake (6 ml. kg^{-1} BW every 2–3 h a day before the test) to keep themselves hydrated for the experimental trials.

Table 1: Carbohydrate and potassium content in 100 g of coconut sports gel and placebo

Trial	CHO (g)	K^+ (mg)
CSG	26	381
PLA	26	0

CSG: Coconut sports gel, PLA: Placebo, CHO: Carbohydrate, K^+: Potassium

Experimental trials

Upon arrival to the laboratory, subjects were required to rest for at least 15 min and measurements such as blood pressure, blood glucose (ACCU-CHEK® Advantage III, USA), blood lactate (Accutrend Plus Meter, USA), urine specific gravity (USG) (Atago UG-a, Japan) and BW (Seca 803, UK) were recorded. Subjects were given a standardised breakfast that consisted of a piece of bread and 250 ml of chocolate and malt powder drink (Milo®) and rested for 1 h. After an hour, subjects were asked to empty their bladders; urine samples were collected and tested for USG as well as their BW were measured. All these measurements were recorded as the baseline results.

Subjects performed a 5 min of dynamic warm up. Subjects proceeded to perform the Cognitive Performance (I) Test which consisted of a 10 × 10 concentration grid (Harris 1982) test, and simple and choice reaction time (RT) tests. For the 10 × 10 concentration grid test, subjects were required to slash out numbers from 00 to 99 in the ascending order within 1 min and the total number slashed was recorded (Greenlees et al. 2006), followed by simple & choice RT test (Moart Reaction and Movement Time Panel, Lafayette, IN) where subjects responded by pressing on the correct stimulus in a 10 repetition ×3 sets arrangement for both RT test and the average time of the 3 sets were recorded (Merk 2017).

Prior to starting the Anaerobic Capacity (I) Test (vertical jump (VJ) and repeated sprint ability (RSA) tests), subjects performed 20 m sprints at 50%, 75% and 90% speed as warm up exercises. Subjects performed the VJ test (Vertec, Sport Imports, USA) with 3 trials of maximum effort and the best score was recorded (Rodríguez-Rosell et al. 2017). Lastly, subjects performed 10-repeated sprints (RSA-1) (Dellal and Wong 2013) and time of each shuttle as well as total time was recorded using Smartspeed timing gates (Fusion Sport, Australia).

Subjects then underwent an exercise-induced dehydration protocol consisting of 60–90 min of cycling on a cycle ergometer to induce a 2% of BW loss. The cadence was maintained at 55–60 rpm with a fixed workload of 60W under hot conditions (35°C–38°C; relative humidity [rh] of 55%–65%). BW was measured at every 30 min intervals. Once subjects achieved a 2% BWL, the exercise was discontinued.

Subjects then performed the cognitive performance (II) and anaerobic capacity (II) tests (C, RT, VJ and (RSA-2) with a ~2% of BWL; USG, blood glucose and blood lactate were collected. Subsequently, subjects were required to ingest sport gels either the CSG (1.2 g CHO. kg^{-1} BW; ~ K^+ = 381 mg) or PLA (1.2 g CHO. kg^{-1} BW) which was prescribed in a randomised order, within 30 min of the 120 min rest interval with a total 1043 ml. kg^{-1} BWL of fluid replacement (Roy 2013).

After 2 h of recovery, BW, USG, blood glucose and blood lactate were measured. Again, BW, USG, blood glucose and blood lactate were measured after undergoing the final series of cognitive performance (III) and anaerobic capacity (III) tests (C, RT, VJ and RSA-3).

All experimental trials were conducted at approximately the same time of day for each subject. Each subject performed 2 experimental trials in randomised order with a washout period of 7 days between trials.

Statistical analysis

A two-way (time × trial) repeated analysis of variance was performed using the IBM Statistical Package for Social Science for Windows version 24.0 (SPSS Inc., Chicago, IL, USA) to compare significance differences within and between treatments. Where significant interaction effects were established, pairwise differences were identified using Tukey's HSD *post hoc* analysis procedure. Where appropriate, differences between trials were also identified using paired sample *t*-tests. All values are expressed as mean ± standard deviation and the significance level was accepted at $P < 0.05$.

RESULTS

Hydration measures

BW was measured to monitor the fluid loss and replacement throughout the experimental trials [Table 2]. After a 2-h rehydration period by ingesting either CSG or PLA with 16 oz. lb^{-1} (1043.18 ml. kg^{-1}) loss, which was approximately 100% fluid replacement, the CSG trial showed 2.5% body fluid retention, whereas for the PLA trial fluid retained was only 2.0%. Even after the final bout of exercise, the CSG trial was able to hold on to more fluid compared to the PLA trial at 0.3% and 0.7% BW loss, respectively. However, there was no significant difference between both experimental trials.

USG was measured to make sure that all the subjects were in a euhydrated condition with USG value of <1.0100. In line with the BW results of this present study was the urine specific gravity (USG) which showed no significant difference [Table 2]. The sport gel and fluid replacement were able to rehydrate the subjects after dehydration with USG measures during dehydration (CSG: 1.0162 ± 0.0077; PLA: 1.0148 ± 0.0061) and after rehydration (CSG: 1.0082 ± 0.0068; PLA: 1.0108 ± 0.0054).

Blood measures: Glucose and lactate

Blood glucose levels were maintained at normal levels throughout the experimental trials in both CSG and PLA treatments [Table 3]. There were no significant differences in blood glucose concentrations between both the experimental trials and it is also observed that there were no drastic fluctuations in blood glucose throughout the four timepoints (4.2–4.7 mmol. L^{-1}). For blood lactate, there was no significant difference between the mean of all four time points between CSG and PLA ($p > 0.05$). Blood lactate levels in both trials significantly increase after Anaerobic Capacity Test (I) (CSG: $p < 0.001$; PLA: $p < 0.001$) and Anaerobic Capacity Test (II) (CSG: $p = 0.022$; PLA: $p = 0.001$) from baseline and after 2-h of rehydration, respectively.

Cognitive performance tests

For concentration ability [Table 4], no significant difference was found between both trials throughout all time points. Mental concentration decreased during the dehydrated state (CSG: 13.0 ± 7.3 no. min^{-1}, PLA: 16.0 ± 3.0 no. min^{-1}, $p = 0.313$) and increased after rehydration (CSG: 20.0 ± 5.5 no. min^{-1}, PLA: 18.0 ± 4.4 no. min^{-1}, $p = 0.380$) as compared with the baseline results (CSG: 18.0 ± 3.2 no. min^{-1}, PLA = 18.0 ± 2.1 no. min^{-1}, $p = 0.609$). However, these changes were not statistically significant.

Table 4 also showed the response time in both trials were similar when subjects were dehydrated (CSG: 61.3 ± 6.5 kg; PLA: 61.4 ± 6.3 kg; $p = 0.751$) and during the post-test (CSG: 62.5 ± 6.6 kg, PLA: 62.2 ± 6.4 kg; $p = 0.132$) tests.

Anaerobic capacity tests

There were no significant differences between the CSG and PLA trials which indicates that the CSG did not have an influence in jump performance. No significant difference between trials in both VJ and RSA tests was reported in Table 5 ($p > 0.05$). This shows that both the CSG and PLA trials did not have any effect on the anaerobic capacity.

DISCUSSION

Hydration measures

Our present study demonstrated subjects ingested 1.2 g CHO. kg^{-1} BW of gel (CSG: ~CHO: 26 g, K+: 381 mg per 100 g gel) during the 2 h of recovery period and showed a 2.5% body fluid retention whereas for the (PLA: CHO: 26 g, K+: 0 mg per 100 g gel) trial fluid retention was only 2.0%. Moreover, after the anaerobic capacity (III) test, greater fluid retention was found in the CSG trial (0.3% BW loss) as compared to the PLA trial (0.7% BW loss). However, there was no significant difference between both experimental trials.

Likewise, in a study which compared hydration between CW from concentrate, bottled water and sports drinks reported that greater fluid retention values observed with CW from concentrate (~52% BW), lowest for bottled water (~35% BW) and intermediate for sport drink (~40% BW); however, there were all statistically not significant ($p > 0.05$) (Kalman et al. 2012). The present study found that both prescribed gels (CSG and PLA) were able to rehydrate the subjects following the 120 min of rehydration period. Similar hydrating effects were observed in both CW and bottled water as compared to a CHO-electrolyte sport drink (6% CHO concentration) (Kalman et al. 2012).

Table 2: Comparison of body weight and urine specific gravity between experimental trials

Parameters	Trials	Baseline	Dehydration	Rehydration	Posttest
BW (kg)	CSG	62.8±6.5	61.3±6.5	62.7±6.6	62.5±6.6
	PLA	62.8±6.4	61.4±6.3	62.6±6.4	62.2±6.4
USG	CSG	1.0039±0.0033	1.0162±0.0077	1.0082±0.0068	1.0039±0.0021
	PLA	1.0045±0.0019	1.0148±0.0061	1.0108±0.0054	1.0042±0.0027

USG: Urine specific gravity, BW: Body weight, CSG: Coconut sports gel, PLA: Placebo

Table 3: Comparison of blood glucose and blood lactate between experimental trials

Parameters	Trials	Baseline	Dehydration	Rehydration	Posttest
Glucose (mmol/L)	CSG	4.6±0.2	4.5±0.2	4.3±0.4	4.3±0.3
	PLA	4.6±0.4	4.6±0.3	4.8±0.2	4.6±0.5
Lactate (mmol/L)	CSG	1.7±0.2	7.9±2.2	2.8±0.8	7.2±3.1
	PLA	1.6±0.2	7.1±1.8	3.1±0.7	10.1±2.9

CSG: Coconut sports gel, PLA: Placebo

Table 4: Comparison of concentration scores, simple reaction time and choice reaction time between experimental trials

Parameters	Trials	Baseline	Dehydration	Postest
Concentration (no/min)	CSG	18±3.2	13±7.3	20±5.5
	PLA	18±2.1	16±3.0	18±4.4
Simple RT (s)	CSG	0.449±0.035	0.466±0.057	0.430±0.040
	PLA	0.446±0.050	0.445±0.032	0.436±0.022
Choice RT (s)	CSG	0.647±0.066	0.668±0.067	0.627±0.060
	PLA	0.645±0.059	0.637±0.045	0.637±0.028

RT: Reaction time, CSG: Coconut sports gel, PLA: Placebo

Table 5: Comparison of vertical jump and repeated sprint ability between experimental trials

Parameters	Trials	Baseline	Dehydration	Posttest
VJ (cm)	CSG	59.5±9.3	57.3±9.7	59.5±10.0
	PLA	60.6±6.8	60.6±6.9	62.0±9.0
RSA (total time, s)	CSG	33.2±1.5	34.0±1.9	33.3±1.7
	PLA	33.8±2.2	34.6±2.2	33.8±2.4

CSG: Coconut sports gel, PLA: Placebo, VJ: Vertical jump, RSA: Repeated sprint ability

One of the main assumptions to explain greater fluid retention in CSG trials (2.5% BW water retention) would be due to the high potassium content in the CSG that was absent in PLA (2.0% BW water retention). The presence of potassium as one of the electrolyte replacements could have elicited an influence during rehydration as it is one of the major intracellular cations, potentially restoring intracellular fluid volume (Casa et al. 2005). The content of the coconut fruit, particularly CW is naturally rich in potassium but lower in sodium and has been proven to be as beneficial as a sports drink and better than pure water for post-exercise rehydration in some studies (Aragón-Vargas and Madriz-Dávila 2000; Ismail et al. 2007; Pérez-Idárraga and Aragón-Vargas 2011). Besides, Ismail et al. (2007) found that rehydration with CW resulted in better fluid retention than water alone after a 3% BW dehydration (65.1% ± 1.7% vs. 58.9% ± 9%, $p < 0.05$) as well as similarly (Pérez-Idárraga and Aragón-Vargas 2011) also resulted in fluid retention in CW (71.0% ± 7.9%) than water (55.9% ± 13.5%) ($p < 0.05$).

Nevertheless, one of the main limitations when working with natural sports gel is the inconsistency in its nutrient content in terms of CHO, electrolytes, and other substance as difference in region, coconut species and maturity will influence the result (Halim et al. 2018; Vigliar et al. 2006; Yong et al. 2009). The CHO content from different batches of coconuts in the CSG production may, particularly the bioavailability of sugar influences fluid retention (Kamijo et al. 2012; Osterberg et al. 2009).

Blood measures: Glucose and lactate

There was no significant difference in blood glucose concentrations between both the experimental trials and it is also observed that there were no drastic fluctuations in blood glucose throughout the four timepoints (4.2–4.7 mmol. L^{-1}). One of the reasons was the intensity of the exercise protocol in the present study was not high enough to induce glycogen depletion as the exercise induced dehydration protocol was a 60–90 min low intensity cycling (65W, 55–60 rpm) under heated conditions; intended to lose BW via perspiration. Prolonged steady-state exercise is associated with an increase in lipid oxidation and a decrease in CHO oxidation rates, according to the findings by Watt et al. (2002). This increase in free fatty acid contribution to energy expenditure as a result of the shift in lipid oxidation reduces the reliance on muscle glycogen (Watt et al. 2002).

Besides, the RSA was only a short duration test (<40 s) which utilised mostly phosphocreatine (PCr) and existing adenosine triphosphate (ATP) but did not cause glycogen depletion. Therefore, there was no sudden change in glucose level even after the sprint performance. In line with the current study was a study by Saat et al. (2002) after exercise-induced dehydration the plasma glucose concentration was between 4.30 and 4.52 mmol. L^{-1} but still within the normal range (Saat et al. 2002). During the CW trial, plasma glucose was only significantly higher compared with plain water (PW) during the first 90 min but at 120 min it was similar to PW (Saat et al. 2002).

The blood lactate level during the post-test in the PLA trial was higher than the CSG trial (10.1 ± 2.9 mmol. L^{-1} vs. 7.2 ± 3.1 mmol. L^{-1}). However, no statistically significant difference was found in blood lactate between the CSG and PLA trials at all time points. Similar findings were reported that no significant difference was found in blood lactate during exercise ($p > 0.05$) among the three beverages (water, glucose, CW) throughout the trials (Alis et al. 2016). Other literature that investigated prolonged exercise with CHO ingestion on blood lactate levels, results observed that subjects running at 70% of $VO_{2\ max}$ to exhaustion had no difference in measured lactate levels when they were given CHO compared to PLA (Tsintzas et al. 1996). Besides, cycling at 70% of their $VO_{2\ max}$ until fatigue also showed no significant difference in blood lactate levels when subjects were given glucose during the prolonged exercise (Coggan and Coyle 1987).

There was a larger increase in blood lactate during the post ingestion of sport gels (Rehydration: 3.1 ± 0.7 mmol. L^{-1}; post-test: 10.1 ± 2.9 mmol. L^{-1}: $p = 0.002$) timepoint in the PLA trial compared to the CSG trial (Rehydration: 2.8 ± 0.8 mmol. L^{-1}; post-test: 7.2 ± 3.1 mmol. L^{-1}; $p = 0.011$). However, when comparing between both CSG and PLA trials on these 2 timepoints, no significant difference was found ($p = 0.162$). Likewise, a study by Krustrup et al.(2006) measured blood and muscle lactates during a soccer game prioritising sprint performance. The said study results showed that after intense periods in the first and second halves, muscle lactate levels were 15.9 ± 1.9 and 16.9 ± 2.3 mmol. kg^{-1} respectively, which was four times higher than at rest, but this did not reflect on blood lactate level (6.0 ± 0.4 and 5.0 ± 0.4 mmol. L^{-1} respectively) as they do not correlate, indicating that blood lactate was a poor indicator of muscle lactate. Hence, this statement also supports the findings of the current study, in which a significant increase in blood lactate between baseline and post-test of both trials (CSG: $p = 0.003$; PLA: $p = 0.000$) was observed but not RSA performance.

This might be due to the similarity of the CSG and PLA gels content with both containing the same CHO prescription at 1.2 g CHO. kg BW^{-1} and the only difference between them is the presence of potassium.

Cognitive performance

The concentration scores, simple and choice RT time in this present study remained similar throughout all time points [Table 4]. Although the present study managed to induce an average of 2.5% BW loss, the magnitude of dehydration is not large enough to cause any noticeable cognitive impairment. This explains that concentration in soccer is not influenced by moderate dehydration (2-3% BW loss), and this would be compatible with the present study and previous observations on the performance of choice RT under different levels of hydration and heat stress (Serwah and Marino 2006).

Similarly, Cian et al. (2001) who looked into cognitive performance with exercise induced dehydration of 2.8% BW loss showed no significant difference ($p > 0.05$) in terms of RT and unstable tracking as these tasks were insensitive to dehydration, hence performance was maintained throughout the experimental duration with a recorded glycemia level ranging at 4.7–9.2 mmol. L^{-1}. Nevertheless, dehydration up to 3%–5% of BW loss not only impairs tracking and attention but also has an impact on simpler tasks such as choice RT (Bradley and Higenbottam 2003).

On the other hand, one of the studies that investigated CHO mouth rinse by Cherif et al. (2018) determined that a several times of 10% CHO-MR after repeated sprint exercise has no influence on the RT tasks (glucose not reported). Similarly, Kumar et al. (2016) found that 5-secs of 6% CHO mouth rinse failed to show improvement in a 20-min continuous performance task that includes cognitive test emphasizing on sustained attention, working memory, response time with blood glucose maintained above 3.6 mmol. L^{-1} over all time points across treatments (2.5 mmol. L^{-1} is considered hypoglycaemic).

Most of the studies which observed no improvements in cognitive performance had one factor in common which is an undisturbed glucose level throughout the experimental trial. It is observed that as cognitive processes are important to the cognitive actions and considering the role of blood glucose in the maintenance of brain function (Hills and Russell 2018), it is therefore explained that cognitive performance in the current study did not elicit significant improvement nor decrements as glucose level at all time points were maintained at normal level in the range of 4.2–4.7 mmol. L^{-1}. Hence, it is suggested that CHO supplementation from the CSG did not enhance the subject's ability to perform better cognitively due to the sufficient glucose availability throughout the experimental trials.

The cognitive tests in the current study were carried out in thermal neutral conditions (27.2°C ± 1.1°C; 45.3% ± 5.4% rh). Therefore, the absence in heat stress might have led to no significant deterioration in cognitive performance; as subjects from current study might mostly be acclimated to heat and dehydrated conditions as they frequently train and compete under hot conditions as heat acclimated athletes have been proven to have better RT (Heled et al. 2012). However, it is also possible that the small sample size used in this study was insufficient to detect differences if it exists (Welsh et al. 2002).

Meanwhile, suggestions for the future could include a higher BW loss percentage (>3%) and introduction to thermal stress might be able to examine deterioration in cognitive performance. Besides, an exercise induced muscle glycogen or glucose level depletion could be adopted to mimic soccer match scenarios and would be able to yield more beneficial results.

Anaerobic capacity

There were no significant differences between the CSG and PLA trial which indicates that the CSG did not have an influence in jump performance. However, this outcome does tally with other studies that looked into CHO ingestion on jumping performance. Currell et al. (2009) used a reliable maximum jump height test during a soccer heading drill between CHO (7.5% CHO solution, 55 g. h^{-1}) and PLA ingestion which resulted in absence of significant differences in performance during a 90-min soccer simulation.

However, a similar study (Přibyslavská et al. 2016) which involved 6% CHO mouth rinse on running and jumping did not improve performance in female soccer players. The highest single VJ scores were maintained throughout the three time points with the first at (CHO: 47.3 ± 3.4 cm, PLA: 47.7 ± 3.5 cm; $p = 0.43$), second (CHO: 48.0 ± 4.1 cm, PLA: 47.9 ± 3.5 cm; $p = 0.82$) or third bout (CHO: 47.4 ± 3.9 cm, PLA: 48.1 ± 3.9 cm; $p = 0.26$). Hence, it is concluded in this study that CHO mouth rinse was not able to influence jumping performance. In another study by Welsh et al. (2002) reported no significant improvement was found in the 30-s 10-repetition vertical-jumping test either CHO-electrolytes (5 mL·kg^{-1} BW of a 6% CHO solution [60 g·L^{-1}] and 18% CHO solution [180 g·L^{-1}]) or flavoured water PLA.

Although there are minimal findings on jump performance and CHO ingestion, a study by Winnick et al. (2005) showed that there were beneficial effects of CHO ingestion on jump performance that demonstrates improvement in mean jump height during 20 repeated maximum jumps of a simulated game with 6% CHO solution (41 g. h^{-1}) compared to PLA. Therefore, these findings show similar outcomes to our study; that both the CSG and PLA trials (~37.5 g. h^{-1}) did not have any effect on the anaerobic capacity.

Furthermore, there was no significant decrease in terms of total sprint time performance in both experimental trials. When it comes to looking at improvement in repeated sprint performance linked to glucose availability in the blood (Welsh et al. 2002) that may allow greater energy metabolism, therefore enables better maintenance of power output (Winnick et al. 2005). There are other findings (Phillips et al. 2011) which also obtained a similar outcome in which CHO gel supplementation (100% maltodextrin CHO gel; 0.78 g. kg^{-1} BW of CHO) did not significantly improve mean sprint time ($p = 0.34$) and peak sprint time ($p = 0.81$) during the Loughborough intermittent shuttle test (LIST). Similarly, a study by Phillips et al. (2010) also observed that LIST performance by ingesting 6% CHO-electrolyte solution, mean sprint time ($p = 0.35$) and peak sprint time ($p = 0.08$) had no significant differences.

These conditions could be explained by Greenhaff et al. (1994) which looked into the metabolic responses of type I and II muscle fibres during maximal treadmill sprints. The study reported that PCr concentration and the rate of regeneration are more relevant to short-duration sprint performance rather than CHO availability which could explain why CHO ingestion did not influence present study's RSA as the total sprints were only approximately 30 s.

However, in this present study our aim was to induce BW loss through the exercise-induced dehydration protocol but not to induce fatigue. Therefore, CHO content in the CSG did not cause a noticeable improvement in the RSA as glucose levels throughout the experimental trial were maintained at normal levels (4.0–5.4 mmol. L^{-1}). The exercise induced dehydration performed by the subjects was at such a low intensity that it did not cause the readings to drop to a hypoglycaemic level.

CONCLUSION

In conclusion, the ingestion of 1.2 g CHO. kg^{-1} BW of CSG (CSG: ~CHO: 26 g, K+: 381 mg per 100 g gel) was able to retain greater body water within 2 h as compared to PLA. Due to the duration of exercise and body water loss during post-test was minimal in the present study, therefore, the ergogenic effect of the CSG was not detectable. It is recommended that future research could mimic the environmental conditions, the duration and intensity during a match to determine the ergogenic effect of the CSG.

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Conflicts of interest

There are no conflicts of interest.

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