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ABSTRACT

The carbohydrate-electrolyte mouth rinse has been widely documented as one of the cooling strategies that attenuate the rise in core temperature and subsequently contribute to enhanced exercise performance. However, this is the first study investigating the effects of sports drink mouth rinse (100Plus®) on trained junior cyclists during 15-min time trial performance in the warm-humid environment. This study aimed to investigate whether sports drink mouth-rinse (carbohydrate-electrolytes) conferred performance and thermoregulatory responses benefits while cycling in a hot and humid environment; and whether the timing (pre and during exercise) of rinses was of importance when compared with a control rinsing with plain water only. Eight male Kelantan state junior cyclists ages 17 ± 1.8 years old completed carbohydrate-electrolytes (100Plus®) mouth rinse and control trial (plain water) during the fixed intensity cycling at 55% VO₂max for 45-min and 15-min work-dependent self-paced cycling time trial. Each cyclist rinsed his mouth with 25 ml bolus (100Plus®) sports drink or plain water at every 15-min (15, 30 and 45-min) for 10-second during the duration of fixed intensity cycling. Heart rate, rectal and skin temperatures, and Borg's rating of perceived exertion (RPE), thermal discomfort and sensation scale were recorded. Results showed that 100Plus® mouth rinse did not improve cycling performance in thermally stress and demonstrated a higher work completed in control (144.7 ± 15.8 kJ) compared to sports drink mouth-rinse (126.2 ± 20.2 kJ) trials. Thus, the most obvious finding from this study was that sports drink mouth-rinse before and during exercise were unable to improve exercise performance in a warm and humid environment.

Keywords: Mouth rinse, cycling performance, warm and humid
INTRODUCTION

Excessive fluid loss or dehydration, as a result, impairs an athlete’s physical performance especially in a hot and humid environment (Ferreira, Farias-Junior, Mota, Elsangedy, Marcadenti, Lemos, Okano, & Fayh, 2018). The athletes are advised to drink enough fluid to replace sweat losses or consumed electrolytes beverages during exercise to maintain homeostasis thus exercise performance will not be compromised (Kerksick, Wilborn, Roberts, Smith-Ryan, Kleiner, Jäger, Collins, Cooke, Davis, & Galvan, 2018; Racinais, Cocking, & Périard, 2017). The finding on Silva, Barros, Mendes, Garcia, Valenti, de Abreu, Garner, Espindola, & Penha-Silva, (2019) suggests that hot temperatures reduce exercise performance and increase the probability of disorders caused by maximal effort. Carbohydrate supplementation can delay the onset of fatigue and improve work output and capacity (Ali, Moss, Yoo, Wilkinson, & Breier, 2017), with the combination of an appropriate carbohydrates and electrolytes composition and administration regiment subsequently delivering major benefits to endurance performance (Maughan, Burke, Dvorak, Larson-Meyer, Peeling, Phillips, Rawson, Walsh, Garthe, & Geyer, 2018). The prescriptive use of ingesting carbohydrate-containing sports drinks for anyone exercising at risks of heat illness and ways in which heat illness can be minimised was well researched. Furthermore, excessive fluid loss or dehydration, as a result, impairs an athlete’s physical performance especially in a hot and humid environment (Ferreira et al., 2018).

Consuming sports drinks containing 6-8% carbohydrates and 10-20 mmol/L of sodium during exercise lasting longer than 60-min will increase performance (Scrivin & Black, 2018). In addition to the recommendations described previously, a new strategy known as carbohydrate mouth rinse is being studied extensively by refreshing the mouths with carbohydrate solution or sports drinks, rinsing, and spitting without swallowing it during exercise. Carter, Jeukendrup, & Jones (2004) was the first to publish a study on carbohydrate mouth rinse on endurance cyclists. Interestingly they found mouth rinsing with a carbohydrate solution resulted 3% improvements in a time trial cycling performance. Later, several investigations into the carbohydrate mouth rinse effect on exercise performance, take Beaven, Maulder, Pooley, Kilduff, & Cook (2013) for instance, showing that carbohydrate and caffeine
mouth rinse can enhance cycling sprint power production among recreationally trained cyclists. As has been noted, carbohydrate mouth rinse demonstrated beneficial effects for cycling performance in short and intermittent sprint, then Luden, Saunders, D’Lugos, Pataky, Baur, Vining, & Schroer (2016) provided the first evidence that carbohydrate mouth rinse should be considered to be applied in endurance cycling to optimise performance at the late stages of competition. Correspondingly, their protocol consists of 120-min cycling at 55% $W_{\text{max}}$ followed by a 30-km time trial and the cyclists have been given three carbohydrate mouth rinses during the time trial. Similarly, the study on 6.4% glucose mouth rinse improved 40-km cycling time trial performance (Murray, Paris, Fly, Chapman, & Mickleborough, 2018). In running performance, the subjects were able to run 29% longer with carbohydrate mouth rinsing when compared to placebo (Fraga, Velasques, Koch, Machado, Paulucio, Ribeiro, & Pompeu, 2017).

The likely explanation on positive results are related to central nervous system alteration by the presence of carbohydrate in the oral cavity (Fraga et al., 2017), maintained neuromuscular activation during exercise (Bastos-Silva, Araujo, Franco, Melo, Learsi, Lima-Silva, & Bertuzzi, 2017), and an increase in central drive or motivation (Carter et al., 2004). There have been consistent observations of carbohydrate mouth rinse improved exercise performance in short and high intensity, intermittent sprint and endurance cycling and running. Not all studies on carbohydrate mouth rinse proven to improve exercise performance as did not improve 60-min track running performance in female recreational runners (Chryssanthopoulos, Ziaras, Oosthuyse, Lambropoulos, Giorgios P, Zacharogiannis, Philippou, & Maridaki, 2018). In the same way, different concentrations of 3%, 6%, and 12% carbohydrate mouth rinse failed to improve 20-km cycling time trial performance in recreationally active males (James, Ritchie, Rollo, & James, 2017; Kulaksız, Koşar, Bulut, Güzel, Willems, Hazir, & Turnagöl, 2016). On the other hand, in a fasted and glycogen-reduced state, Ali et al., (2017) found carbohydrate mouth rinse showed no performance enhancement among moderately trained male cyclists.

As aforementioned, not all investigations have demonstrated the ergogenic effect of carbohydrate mouth rinse during exercise. Again, all the previous studies have been carried out in thermoneutral condition, contrary to this present study which investigates carbohydrate-electrolytes (sports drink) mouth rinse during exercise in a warm and humid environment. In
the event of the laboratory setting in the thermal stress condition, during open-looped or fixed-intensity protocol and closed-loop or self-selected workloads performance are reduced due to attainment of high core body temperature of 40°C to avoid risk of heat-stroke (Hanson, Martinez, Byl, Maceri, & Miller, 2019; Ruddock, Robbins, Tew, Bourke, & Purvis, 2017). Therefore, a novel aspect of this study is to investigate the impact of sports drink (100plus®, Fraser and Neave Limited, Malaysia) mouth rinse on cycling performance in warm and humid environment. Finding from this study will benefit an athlete as a strategy to reduce heat-related illness during training or competition in the condition of thermal stress. Equally important for Muslim athletes who are training and competing during Ramadhan fasting, sports drink mouth rinse strategy could be advantageous to maintain or improve exercise performance.

RESEARCH METHODOLOGY

Participants

Eight healthy, junior male cyclists provided their informed consent to participate in the study. The participants’ characteristics were (mean ± SD): age, 17 ± 1.8 years; height, 1.7 ± 0.1 m; weight, 57 ± 11.5 kg; VO2peak, 61.2 ± 8.4 ml/kg/min; maximal heart rate, 181 ± 14 beats/min and peak aerobic power, 278 ± 28 W. All participants were well-trained cyclists with at least 2 years of competitive experience at the national level. The protocol was approved by the Human Ethics Committee of Universiti Sains Malaysia (USM/JePEM/19020109) and performed in accordance to the latest Declaration of Helsinki. Participants arrived at the laboratory for all experimental trials having refrained from strenuous exercise, caffeine, and tobacco for a period of 24-h.

Experimental Overview

Participants visited the laboratory on a total of four occasions. In the following order, these visits included: (1) preliminary submaximal and maximal test, (2) experimental familiarization, (3 and 4) experimental trials. All the visits were separated by 7 days, conducted at the same time of day. Experimental trials consisted of a plain water mouth rinse (Control) and 100Plus®
mouth rinse trials. A schematic diagram can be seen in Figure 1. All the trials were completed on an electronically braked cycle ergometer (Excalibur Sport, Lode Groningen, Nederland), used either in the cadence-independent mode (hyperbolic mode, for steady-state) or a cadence-dependent mode (linear mode, for time trial).

**Preliminary Trial and Familiarization**

Following body weight (Tanita, Japan) and height (Seca, Germany) measurements, this session was conducted in a moderate laboratory environment (22-25°C) with a fan located in front of the participants with an airflow of 20 km/h. A submaximal test required the participants to cycle on an electronically brake cycle ergometer (Lode Excalibur, The Netherlands) for 6-min at each of four consecutive submaximal power output which was 100 W, 150 W, 200 W, and 250 W. Following a 30-min rest, VO2max was determined by a ramp protocol with 15 W/min until volitional fatigue. Expired gases were collected continuously (ParvoMedics TrueOne, Murray, Utah, USA) for the determination of ventilation and VO2 and heart rate (Polar Electro Oy, Finland) were collected continuously throughout both tests. Following this, a linear relationship between the mean rate of VO2 during the last 2-min of each submaximal stage and power output was determined and used to calculate a power output which would elicit 55% (steady-state) and 75% (time-trial) of VO2peak for each participant for the remaining three trials.

A familiarization trial was conducted in a warm-humid environment at dry-bulb temperature of 31 ± 0.1°C and relative humidity of 70 ± 0.7% with a fan located in front of the participants with an airflow of 20 km/h. This session was undertaken to ensure the participants were accustomed to the procedures employed during the investigation and to minimise any potential learning or anxiety effects during experimental trials.
Experimental Trials

On arrival to the laboratory subjects voided and nude body weight was measures. Participants then self-inserted a rectal thermistor (YSI Incorporated, United State) to depth of 12 cm beyond the anal sphincter and entered the environmental chamber wearing only cycling short, shoes and socks. The heart rate monitor (Polar Electro Oy, Finland) was positioned across the chest and four skin surface thermistors (YSI Incorporated, United State) were attached to the chest, arm, thigh, and calf on the right side of the body. All thermistors were then connected to temperature monitor (Libra Medical Corporation, United States). Weighted mean skin temperature was calculated according to the equation of Ramanathan (1964).

On the ergometer, participants received either 25 ml bolus 100Plus® or plain water (Control), which they rinsed for 10-sec before expectorating into a beaker. Participants cycled for 45-min at the pre-determined power output that estimated to elicit 55% VO2max with the ergometer set in cadence-independent mode. Every 10-min an expired gas sample was collected for 2-min (ParvoMedics TrueOne, Murray, Utah, USA), and every 5-min heart rate, rectal and skin temperature reading were recorded. Borg’s rating of perceived exertion, thermal
discomfort and sensation scale were taken every 15-min throughout the experimental trials. Every 15-min (at 15, 30 and 45-min) interval, the participants received either 25 ml bolus sports drink or plain water and rinsed the fluid around their mouths for 10-sec, and then spat the fluid back into a beaker.

Immediately on completion of the 45-min steady-state period, the ergometer was set to linear mode, based on the formula of Jeukendrup, Saris, Brouns, & Kester (1996). During this time, the participants were asked to complete as much work as possible in the 15-min with the only information received being when every 3-min had elapsed. Following completion of the time-trial, participants performed a low-intensity cool-down for at least 5-min where recovery was monitored.

**Statistical Analysis**

The statistical analysis was conducted using SPSS software for Windows (IBM SPSS Statistics 24). Data were checked for normality using Shapiro-Wilk test. Paired sample t-test was used to determine the difference between cycling time trial performance between experimental trials (Control vs. Sports drink) whereas all other measures were analysed by 2-way (trial x time) ANOVA for repeated measures with post-hoc pairwise analyses performed where main or interaction effects occurred, with statistical significance set at P<0.05. Sphericity was assessed and where the assumption of sphericity could not be assumed, adjustment to the degrees of freedom were made (ε > 0.75 = Huynh-Feldt; ε < 0.75 = Greenhouse-Geisser).

A two-way (trial x time) repeated measures analysis of variance (ANOVA) was conducted to determine the difference between trials on core temperature, skin temperature, heart rate, and RPE. Descriptive values were obtained and reported as means and standard deviation with statistical significance set at p<0.05.
RESULT

Time Trial Performance

The average work completed in the 15-min time trial for the control and sports drink trials were 144.7 ± 15.8 kJ and 126.2 ± 20.2 kJ, respectively (Figure 2). Participants work completed in the 15-min time trial significantly greater (p<0.05) during control trial compared with the sports drink trial.

![Figure 2. Total work completed (kJ) during 15-min time trial for control and sport drink Mouth rinse trials. Data are expressed as mean ± SD.* indicates significantly different to Control.](image)

Thermoregulatory Responses

Thermoregulatory measures of rectal and mean skin temperatures are depicted in Figure 3. There was no significant difference of rectal temperature between control and sports drink trials (p=0.98, p>0.05). There was a significant effect of rectal temperature with time (p<0.001). Pre-
cycling rectal temperature were similar between both trials (p>0.05; control: 37 ± 0.5°C; sports drink mouth rinse: 37.1 ± 0.4°C). Meanwhile during cycling, rectal temperature increased above resting levels from 5-min and continued to rise, such that rectal temperature was higher for sports drink trials during the time trial. Similarly, there was no significant difference of mean skin temperature between control and sports drink trials (p>0.05). However, there was a significant effect of mean skin temperature with time (p<0.001).

Figure 3: Rectal temperature (a), and mean skin temperature (b) at rest, steady-state cycling and 15-min time trial for control trial (▲) and sports drink trial (□). Data are expressed as mean ± SD. # denotes significant main effect of time (p<0.01).
Cardiovascular Response

There was no significant mean difference of heart rate between control and sports drink mouth rinse trials (p=0.831, p>0.05). However, a significant effect of heart rate with time (p<0.001) was observed which increased from 125 ± 18.1 and 125 ± 4.5 bpm after 5-min to 135 ± 16.7 and 136 ± 6.4 bpm at 45-min before increasing further to 148 ± 32.3 and 164 ± 12.7 bpm at the end of the time trial for the control and sports drink mouth rinse trials, respectively (Figure 4).

![Figure 4: Heart rate for control trial (▲) and sports drink trial (□). Data are expressed as mean ± SD. # denotes significant main effect of time (p<0.01).](image)

Perceptual Responses

There was no significant mean difference of rate of perceived exertion (RPE) between control and sports drink trials (p=0.528, p>0.05). There were significant differences for all mean RPE scores with the time for both control and sport drink trials (p<0.01). As can be seen in Figure 5, perceived exertion during steady-state cycling remained constant (10 ± 2) but increased (p<0.05) following time trial (12 ± 3). In thermal discomfort response, there was no significant
mean difference of thermal discomfort scales between trials (p=0.555, p>0.05). Similarly, no significant mean difference of thermal sensation scales between both trials (p=0.315, p>0.05).

(a)

![Graph](image1)

Steady-state Cycling | Time Trial
10 20 30 40 50 60
RPE
6 8 10 12 14 16 18

(b)

![Graph](image2)

Steady-state Cycling | Time
10 20 30 40 50 60
Thermal Discomfort
Very Comfortable
Uncomfortable
Slightly Uncomfortable
Comfortable
0 1 2 3

Thermal Sensation
Very Comfortable
Uncomfortable
Slightly Uncomfortable
Comfortable
0 1 2 3 4 5 6 7

Figure 4: RPE (a), thermal discomfort and thermal sensation (b) for control trial (▲) and sports drink trial (▲). Data are expressed as mean ± SD.

# denotes significant main effect of time (p<0.01).

* denotes a significant difference from 10-min (p<0.05).
DISCUSSION

This is the first study investigating the effects of sports drink (100Plus®, Fraser and Neave Limited, Malaysia) mouth rinse on 15-min time trial performance in the warm and humid environment on trained junior cyclists. It was hypothesised that a sports drink mouth rinse prior and during cycling exercise would improve mean work completed in 15-min time trial in trained cyclists. But based on the present result of the time trial, it was clearly showed that sports drink mouth rinse did not improve cycling performance in thermally stressed with higher work completed in control (144.7 ± 15.8 kJ) compared to sports drink mouth rinse trials (126.2 ± 20.2 kJ). This outcome is contrary to that of Che Muhamed, Mohamed, Ismail, Aziz, & Singh (2014) who found the enhancement in performance with mouth rinsing among Ramadan-fasted cyclists in hot and humid condition. According to Lane, Bird, Burke, & Hawley (2013), there was an increase in average power output with a 10% CHO solution. However, in accordance with the present time trial result, the previous study of Ferreira et al., (2018) has demonstrated that mouth-rinse intervention was not effective in enhancing the performance of cyclists in the 30-km time trial. This present finding may be somewhat explained by antipathy of sports drinks mouth rinse during exercise as most of participants complained uncomfortable and sticky saliva after a series of sports drink mouth rinsing. Beelen, Berghuis, Bonaparte, Ballak, Jeukendrup, & van Loon (2009) also reported mouth rinsing with an isotonic solution did not improve the 1-h cycling time trial compared to water rinse placebo.

Desbrow, Anderson, Barrett, Rao, & Hargreaves (2004) found that sports drink mouth rinse does not improve the cycling performance during short high-intensity exercises of less than 60-min due to the influence of dietary variables on high-intensity cycling performance of approximately 1-h duration. Watson, Nichols, & Cordery (2014) investigation also failed to support the role of oral sensing of carbohydrate in influencing performance during prolonged exercise in warm conditions, in contrast to several published studies (Fares & Kayser, 2011; Gam, Guelfi, & Fournier, 2013) demonstrating significant improvements in cycle time trial performance in temperate conditions. Although carbohydrate mouth rinse strategy has been included in American College of Sports Medicine (ACSM) as one of the alternatives to
carbohydrates replacement in short-duration exercises (Ferreira et al., 2018; Thomas, Erdman, & Burke, 2016), the present study did not observe improvements on performance.

Recent evidence showing ergogenic effects of mouth rinsing carbohydrate on endurance performance is substantial. However, there is still a lack of dose-effect research. Wright & Davison (2013) concluded that mouth rinsing with a carbohydrate-electrolytes solution increases endurance running efficiency but there is no dose-response effect with a higher concentration (12%) compared to a standard 6% solution. James et al., (2017) also found that mouth rinsing and expectorating a solution of 7% maltodextrin was routinely correlated with improved cycle time trial output of about 1-h in length for 5-secs during exercise and also increasing the rinsed solution's carbohydrate concentration from 7% to 14% resulted in no further improvement in performance.

The finding of the current study also does not support the previous research with alteration of thermoregulatory response (core temperature) that lead to decrement exercise performance in tropical environments, which had the combination of heat and high humidity environment. Therefore, it was proposed that a high core temperature caused fatigue (Chabert, Hermand, & Hue, 2019). It is surprising that core temperature only reached a maximum of 38°C at the end of the time trial for both trials and without increasing further to an alarming rate. A significant decline in power output has been observed when core temperature exceeds 38.5°C (Al-Horani, Wingo, Ng, Bishop, & Richardson, 2018). On the contrary, the finding of the current study on the rectal temperature does not reflect the time trial performances where core temperature peaked around 38.5°C or less, with the power output maintained. Furthermore, the self-paced time trial was significantly decreased in the hot environment but without differences in performance at a core temperature of 38.2°C (Ely, Cheuvront, Kenefick, & Sawka, 2010). A possible explanation for core temperature response might be that participants in this study were young and well-trained cyclist who are accustomed to the warm and humid environment as they were regularly training and participating in cycling race throughout the year. Endurance-trained and heat-acclimatised individuals who are well-hydrated have less body heat storage and perform optimally during exercise-heat stress (Sawka, Young, Cadarette, Levine, & Pandolf, 1985). It seems repeated heat exposure leads to a decrease in core temperature during
Experimental trials (Racinais, Sawka, Daanen, & Périard, 2019). In addition, the researchers speculated that short (less than 2-h) exposure to hot and humid condition in the laboratory during experimental trials was associated with lowering core temperature (below 39°C) at the end of the exercise.

Regardless, the factors that influence one's RPE during exercise are extremely complicated as RPE is believed to be influenced by various factors, including effort, strain, pain, discomfort and or fatigue (St Gibson, Lambert, Rauch, Tucker, Baden, Foster, & Noakes, 2006). Furthermore, Abbiss, Peiffer, Meeusen, & Skorski (2015) found that there was a dissociation between the RPE and heart rate when exercising at low or maximal such as all-out intensities. However, RPE during steady-state cycling remained constant but increased following time trial based on this present finding. Therefore, the RPE is highest at the end of the time trial due to the participants performing an ‘all-out’ effort at their self-paced cycling to complete as much work as possible in 15-min time trial. Thus, Bridge, Weller, Rayson, & Jones (2003) reported that exercise in a hot environment showed a higher RPE rating compared to similar exercises in cooler environments, indicating a greater hesitancy to continue exercising. The RPE increased significantly in both trials in the Mündel, King, Collacott, & Jones (2006) study, from subjects rating their exertion as 'light' to values representing exertion as 'very hard' at the end of exercise. Pires, Brietzke, Pinheiro, Veras, De Mattos, Rodacki, & Ugrinowitsch (2018) observed that the lower RPE slope in the condition of carbohydrate mouth rinse might also be an advantage in time trial competitions, as the slower rise in RPE throughout the trial may enable cyclists to boost the effort at the end of a race. Therefore, the RPE and effort are both considered extremely important in the regulation of intensity during self-paced physical activity (Abbiss et al., 2015).

In summary, one of the more significant findings to emerge from this study is that sports drink (100Plus®, Fraser and Neave Limited, Malaysia) mouth rinse is not the first choice for performance improvement technique compared to other hydration strategies for young well-trained cyclists competing or training in a warm and humid environment. The finding of this research provides insights for one of practical cooling strategy (mouth rinse) strategies to improve exercise performance in real training session and competitions in warm and humid environments.
environment. However, the sports drink mouth rinses such 100Plus® strategy appeared to not affect 15-min cycling time trial performance. Nonetheless, when attempting to generalise this study finding, further consideration must be given to some of the limitations of the current research and hence what future research is warranted. The strongest limitation of this work lies in the potential for a placebo effect as compared to water-only control and limited by the absence of diet and physical activity control prior to experimental trials as most of the participants were called up to undergo their training programme.

REFERENCES


