The effect of carbohydrate mouth rinsing on fencing performance and cognitive function following fatigue-inducing fencing

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Abstract

This study investigated the impact that mouth rinsing carbohydrate solution has on skill-specific performance and reaction time following a fatigue inducing bout of fencing in epee fencers. Nine healthy, national level epee fencers visited a laboratory on 2 occasions, separated by a minimum of 5 days, to complete a 1-minute lunge test and Stroop test pre and post fatigue. Heart rate and ratings of perceived exertion (RPE) were recorded during completion of the fatiguing protocol. Between fights the participants mouth rinsed for 10 seconds, either 25ml of 6.7% maltodextrin solution (MALT) or water (PLAC). Blood lactate and glucose were recorded at baseline, pre- and post-testing. Results showed an increase in heart rate and overall RPE over time in both conditions. There were no differences in blood glucose (F(1,8)=.63, P=.4, η^{p}=.07) or blood lactate levels (F(1,8)=.12, P=.70, η^{p}=.01) between conditions as a function of time. There was a significant improvement in lunge test accuracy during the MALT trial (F(1,8)=5.21, P=.05, η^{p}=.40) with an increase from pre (81.2 ±8.3%) to post (87.6 ±9.4%), whereas there was no significant change during the placebo (pre 82.1 ±8.8%, post 78.8 ±6.4%). There were no recorded differences between conditions in response time to congruent (F(1,8)=.33, P=.58, η^{p}=.04) or incongruent stimuli (F(1,8)=.19, P=.68, η^{p}=.02). The study indicates that when fatigued mouth rinsing MALT significantly improves accuracy of skill-specific fencing performance but no corresponding influence on reaction time was observed.

Keywords; epee, fatigue, mouth rinsing, reaction time, skill

Introduction

The ergogenic effect of carbohydrate (CHO) supplementation on endurance, high intensity, and intermittent performance has been extensively reported (Burke et al., 2001; Black et al, 2012; Hargreaves, Hawley, and Jeukendrup 2004). Furthermore, research investigating the effects of CHO ingestion during sports requiring high levels of motor and cognitive skill have evidenced improvements in skill-specific performance (Bottoms, Hunter and Galloway, 2006; McRae and Galloway, 2012). Attempts to elucidate the mechanisms underpinning CHO supplementation effects point to the direct influence of CHO oxidisation rates during prolonged exercise (>2 hours) where skeletal muscle and liver glycogen stores are a limiting factor (Cermack and van Loon, 2013). However, given that 5-15g of exogenous CHO is oxidised during the first hour of exercise (Jeukendrup et al., 1997) it becomes questionable whether such mechanisms explain performance benefits during exercise sessions lasting less than 1 hour or during intermittent exercise. Addressing this critique, evidence points to a central nervous system (CNS) response to CHO exposure within the oral cavity during shorter periods of high-intensity exercise (<1 hr.) (Carter, Jeukendrup and Jones, 2004; Chambers, Bridge and Jones, 2009). By exposing oral cavity receptors to glucose maltodextrin, brain regions of reward and motivation are stimulated and work outputs increase (Chambers, Bridge and Jones, 2009). Although the specific mouth receptors involved in detecting CHO are yet to be identified, a growing number of studies advocate the role that a CNS pathway plays in moderating a CHO-performance effect.

Carter, Jeukendrup and Jones (2004) provided the first investigation of CHO effects testing a CNS hypothesis by asking participants to rinse a CHO solution in their mouth before spitting it out, a practice known as carbohydrate mouth rinsing (CMR). Carter and colleagues found cycling time trial (TT) performance significantly improved following multiple CMR episodes compared to a taste-matched placebo. Recent work employing electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) provides further evidence for the role that the CNS plays in moderating the link between CMR and motor/cognitive outcomes (De Pauw et al., 2015; (Turner, Byblow, Stinear, & Gant, 2014). For example, Turner et al. (2014) recently showed that during CMR images from fMRI showed localised increases in blood oxygenation levels specific to the contralateral primary sensorimotor cortex which are commonly associated with increasing functional activation during a motor task. Oral CHO was also associated with activation in early visual regions responsible for processing task instructions (Turner et al., 2014). Although this emerging body of evidence offers enough encouragement to suggest that future work is warranted at present it is appropriate to conclude that the mechanisms underlying CMR effects remain undetermined.

A range of studies have to date demonstrated that CMR improves performance in sports that last under 1 hour (Chambers et al., 2009; Fares and Kayser, 2011; Lane et al., 2013; Phillips et al., 2014; Rollo et al., 2008; Rollo et al., 2010; Sinclair et al., 2014). Sinclair et al. (2014) demonstrated an increase in distance covered in 30 minutes with CMR compared to a placebo through an increase in power output and maintained RPE. Very few studies have investigated the effects of CMR on intermittent exercise, with mixed findings (Beaven, Maulder, Pooley, Kilduff, & Cook, 2013; Dorling & Earnest, 2013). There has only been one apparent study to date which has investigated intermittent sports performance (Přibyslavská et al., 2015). The authors measured power output via vertical jump and sprint performance rather than skill based performance measures in American Football and found no effect on performance. Variations in findings could be attributed to a range of factors, including the duration and frequency of exposure to CMR (Sinclair et al., 2014), participants' training and nutritional status, or exercise mode and intensity (Fares and Kayser, 2011; Lane et al., 2013). This irregular picture of CMR effects is also evident in studies including cognitive measures such as the Stroop test. For example, Sanders et al. (2012) found CMR significantly improved reaction times. Conversely, De Pauw et al.

(2015) found no significant difference in response time to congruent or incongruent stimuli when a MALT solution was mouth rinsed. Taken together the CMR literature provides mixed evidence for adaptive physiological effects during intermittent exercise and mixed but encouraging results when considering skill and cognitive outcomes. It is clear that less is currently known about the latter two categories of outcome which in itself dictates a need for more work in this area.

Fencing is an open-skilled Olympic and Para-Olympic combat sport, characterised by short bursts of high intensity exercise followed by periods of rest (Bottoms, Greenhalgh and Gregory, 2013). To this end, CMR offers a practical intervention strategy for sports scientists; in competition each poule fight lasts for a maximum of 3 minutes followed by approximately 6 minute rest period, allowing ample time mouth rinsing between fights without affecting recovery. Fencing is further characterised by rapid motor performance, for example an attack, followed by periods of low intensity 'bouncing' movements. To date there is little research investigating factors affecting fencing performance, however studies have identified that adequate psychological condition is required to prevent central and peripheral fatigue (Roi & Bianchedi, 2008). Work in other skill-based intermittent sports such as tennis has established an attenuating effect of fatigue on skill maintenance (Davey, Thorpe, & Williams, 2002; Hornery et al., 2007). Research investigating the influence of cognitive and physiological fatigue on skill-performance, mainly within tennis and cycling, has found fatigue inversely effects skill-performance (Davey, Thorpe, & Williams, 2002; Hornery et al., 2007; Royal et al., 2006). Therefore an epee fencer’s responses and subsequent performance could be improved by delaying the onset of fatigue. As previously mentioned, CMR improves performance by increasing motivation and delaying fatigue (Carter, Jeukendrup and Jones, 2004), in addition to potentially improving cognitive function (Sander et al., 2012) and neuromuscular function (Jeffers et al., 2015). As fencing requires a high degree of skill, decision making and reaction times, increasing motivation and improving cognitive function could have a benefit to performance. Therefore this study aimed to investigate the effect of CMR on fencing performance. We hypothesised that under CMR conditions skill-specific performance and cognitive function of epee fencers following a fatigue inducing fencing protocol will be superior to performance under placebo condition.

Method

Participants

Nine national standard fencers (minimum of 9 years' experience) (two female; seven male; 31.2 ± 14.3 years; body mass 81.4 ± 16.5 kg; height 178 ± 8 cm) who regularly compete in fencing competitions and train a minimum of twice per week volunteered to participate. All participants completed a physical activity questionnaire to ensure they were healthy and injury-free. Participants gave written consent prior to participating. The study was granted approval by the lead author's institution.

Procedure

Participants visited the laboratory twice, separated by a minimum of five days (maximum 10 days separation) in a single blinded experiment with conditions randomised for order. For each visit to the laboratory the participants were required to fast, following breakfast, for a minimum of four hours prior to the start of testing on each day. This duration would not be uncommon for athletes to go without food for this time in the lead up to training or competition. They also replicated their food intake for 48-hours prior to each test session. Post-test, all participants reported adhering to these instructions. Participants were always tested at the same time of day to avoid interference from differences in circadian rhythms. Each participant completed two trials involving a fencing specific skill-test and a cognitive function test both pre- and post-completing a fencing fatiguing protocol. They had a practice go on the lunge and cognitive test at the beginning of each trial to familiarise them. All fencers used their own protective equipment and swords, thus replicating competition conditions. Using capillary sampling (20μl) at the finger, blood samples for baseline glucose and lactate (Biosen C-Line, EFK Diagnostics) were obtained upon arrival and followed by a self-directed 5-minute moderate intensity warm-up, consisting of 2 minutes jogging, 2 minutes stretching and 1 minute of fencing-specific footwork exercises. During the warm-up period the participants were not permitted to practice the target striking exercise.

Following this participants completed cognitive function and skill-tests. Further blood glucose and blood lactate measurements. The fatigue protocol simulated a series of six fights replicating the first round of a standard epee fencing competition (Bottoms et al., 2009). After each fight during the fatigue protocol, heart rate (HR) was recorded (Polar f51 monitor) and ratings of perceived exertion for the sword arm (RPE_{arm}), legs (RPE_{legs}) and total ($RPE_{overall}$) recorded using a 20-point Borg scale (Borg, 1982). Participants' mouth rinsed an intervention solution between each fight for 10 seconds before spitting out. Blood glucose and blood lactate samples were taken immediately after completing the fatigue protocol, followed by the cognitive function and skill tests. Both visits to the laboratory followed the same protocol but participants were given the alternate solution to mouth rinse (blind to condition).

Participants' mouth rinsed 25 ml of 6.7 % maltodextrin mixed into water (MALT) or 25 ml of water (PLAC). Between each fight participants swilled the solution around their mouth for 10 seconds before spitting it into a measuring jug to record the amount spat out.

*Cognitive Function. P*articipants performed a Stroop test consisting of 40 word-colour combinations, both incongruent and congruent (E-Prime 2.08). Each trial included a familiarisation test consisting of 8 word-colour combinations. The total response time and accuracy of answers were recorded.

Skill Test. The skill test comprised a lunge test to measure accuracy and speed of hits at a target 8.9 cm in diameter positioned centrally on the chest of a full-size mannequin. Prior to test participants' ideal lunge distance was measured and marked from the position of their front foot and remained constant throughout. Participants were instructed to lunge at the target as quickly and accurately as possible for 1 minute replicating a fencing attack. The test is used for talent identification by British Fencing and all participants reported familiarity with the test. A total score of lunges, hits and misses was recorded.

Fatigue Protocol. Fatigue was induced via completion of a previously validated laboratory based fencing protocol (Bottoms et al., 2009). The protocol simulates six poule fights designed to replicate the first round in a fencing competition. Participants were required to start in the on-guard position facing the fencing dummy. Participants performed a series of bouncing movements with a standardized number of arm extensions, retreats and lunges for a period of 8 seconds before 9 seconds rest. They rested for a maximum of 6 minutes between poules to simulate the rest periods during competition. The work-rest ratio was set at 1:0.8 commensurate with timings from fencing competitions (Roi and Biachedi, 2008).

Data Analysis

The total number of hits during test were recorded pre- and post-protocol for each trial. Lunge test accuracy was calculated by dividing total lunges by 100 and multiplying by number of on-target hits. Mean reaction time and total accuracy to both congruent and incongruent stimuli pre- and post-fatigue protocol for both trials was obtained from E-Prime 2.08. HR and RPE recordings were taken during the fatigue protocol for both trials.

Statistical analysis was conducted using SPSS v.23.0 (SPSS, Inc, Chicogo, IL). Blood glucose and lactate, lunge test accuracy and speed, Stroop test reaction time and accuracy, RPE, and HR measurements were assessed using repeated measures two-way (Treatment X Time) analysis of variance (ANOVA). Post hoc analyses used a Bonferroni correction to control for type I error. In line with the recommendations of Cohen (1988) partial eta squared values of 0.01 were classified as small, effect sizes of 0.06 were classified as moderate and 0.14 or above were classified as large. The alpha level was $P < 0.05$.

Results

Four out of the nine remaining participants were able to correctly identify both solutions post trial. The mean amount of fluid expectorated following mouth rinsing in both conditions did not significantly differ from the total amount mouth rinsed ($P > 0.05$). The mean amount of fluid measured at the end of the trial was 136.89 ±5.53 and 133.33 ±3.64 ml for placebo (PLAC) and maltodextrin (MALT), respectively.

Blood Glucose and Lactate. Blood glucose concentrations remained constant throughout both trials, with no significant effect of time ($F_{2,16}=.712$, $P = 0.52$, $\eta^p=0.49$; Figure 1a). Blood glucose concentration was not affected by MALT with no significant difference observed between trials ($F_{1,8}=0.634$, $P = 0.4$, $\eta^p=0.07$), mean concentrations 4.3 ±0.80 and 4.4 ±0.80 mmol l^{-1} for PLAC and MALT respectively. There was a significant effect of time on blood lactate concentrations in both trials ($F_{2,16}=9.35$, $P = 0.002$, $\eta^p=.62$; Figure 1b). Post-hoc analysis showed blood lactate concentration significantly increased ($P = 0.019$;

Figure 1b) from rest (1.8 ±1.7 and 1.2 ±0.31 mmol l^{-1} for PLAC and MALT respectively) to pre-fatiguing protocol (4.2 ±1.5 and 3.7 ±1.9 mmol l^{-1} for PLAC and MALT, respectively). However, no significant difference was observed between conditions ($F_{1,8}$=0.123, P = 0.71, η^{p}=0.01) indicating that MALT had no effect on blood lactate concentrations.

Figure 1 near here

RPE and Heart Rate. Participants' overall RPE increased throughout the two trials (main effect of time; $F_{2,1}$=1.74, $P < 0.001$, η^{p}=0.85). Similarly participants' RPE for the legs (RPE_{legs}) significantly increased over time in both trials (main effect of time; $F_{5,40}$=11.564, P <0.05, η^{p}=0.89). However participants' RPE for the sword arm (RPE_{arm}) did not change over time ($F_{2,17}$=0.887, P = 0.50, η^{p}=0.01). There was no observed difference throughout testing for $RPE_{overall,}$ ($F_{1,8}$=1.174, P = 0.310, η^{p}=0.12), RPE_{legs} ($F_{1,8}$=0.565, P = 0.474, η^{p}=0.06), and RPE_{arm} ($F_{1,8}$=0.001, P = 0.981, η^{p}=0.10) between trials. Participants' RPE and HR for MALT and PLAC are presented in Table 1. A significant increase in HR was observed in both trials between fight 1 and 2, and 1 and 3 ($P < 0.05$; figure 5). No time by condition interaction for heart rate was observed ($F_{1,8}$=0.026, P = 0.875, η^{p}=0.003).

Table 1 near here

Skill Test. There were no observed differences between the two conditions ($F_{1,8}$=0.302, P = 0.60, η^{p}=0.04) but the mean number of lunges over time increased from 43 ±12 pre-protocol to 47 ±15 post-protocol ($F_{1,8}$=4.182, P = 0.075). A significant interaction emerged for time by condition ($F_{1,8}$=5.818, P = 0.05, η^{p}=0.42) with post-hoc analysis showing a significant increase from 41.9 ±9.8 to 46.7 ±12.9 in total number of lunges pre- and post-protocol in the PLAC trial, but no significant increase in the MALT trial (44.8 ±9.1 and 46.9± 4.5 pre-protocol and post-protocol, respectively). Lunge test accuracy was significantly higher in the MALT condition in comparison to the PLAC ($F_{1,8}=5.214$, $P = 0.05$, $\eta^{p}=0.40$). Inspection of individual results indicates that 7 participants out of 9 improved accuracy post-protocol in the MALT trial. Mean values of accuracy pre- and post-protocol for MALT and PLAC are displayed in Table 2. There was no time main effect across conditions ($F_{1,8}=0.98$, $P = 0.762$, $\eta^{p}=0.01$).

Table 2 near here

Stroop Test. The response time to congruent stimuli was significantly faster post-protocol than pre-protocol in both trials ($F_{1,8}= 5.414$, $P < 0.05$, $\eta^{p}=0.40$; Figure 2). Mean response times were 644.5 ±83.9 and 593.7 ±91.5 ms pre-protocol and post-protocol, respectively. There was no significant difference in response time to incongruent stimuli between pre- and post-protocol in both trials ($F_{1,8}=1.6$, $P = 0.24$, $\eta^{p}=0.17$). There was no main effect for MALT on response time for both congruent ($F_{1,8}=0.326$, $P = 0.58$, $\eta^{p}=0.03$) or incongruent stimuli ($F_{1,8}=0.189$, $P = 0.68$, $\eta^{p}=0.02$) between trials. No main effect for PLAC in relation to accuracy for both congruent ($F_{1,8}=2.485$, $P = 0.15$, $\eta^{p}=0.23$) and incongruent stimuli ($F_{1,8}=0.780$, $P = 0.40$, $\eta^{p}=0.09$). There was also no observed effect of MALT on accuracy for congruent ($F_{1,8}=.001$, $P = 1.00$, $\eta^{p}=0.04$) and incongruent stimuli ($F_{1,8}=0.308$, $P = 0.594$, $\eta^{p}=0.001$).

Figure 2 near here

Discussion

The aim of the present study was to investigate the effect of CMR on cognitive and skill-specific performance following a fatigue-inducing fencing protocol. The results show a significant improvement in accuracy during the lunge test in the MALT condition compared to PLAC. There were no significant differences in speed or accuracy to congruent or incongruent stimuli. The results demonstrated a significant effect of time on $\text{RPE}_{\text{overall}}$ and RPE_{legs}, thus supporting the validity of the fencing fatigue protocol employed.

Mean HR recorded post-fight 6 in the fencing protocol reached 162 ±12 beats.min^{-1} which is similar to the HR ranges recorded during an epee competition (Li et al., 1999). Our findings provide some support for the use of CMR as a nutritional strategy for high level epee fencers.

This study observed a significant improvement in skill-specific performance following CMR. Much of the research reporting effects of CMR on exercise performance has measured steady-state performance (Carter et al., 2004; Chambers et al., 2009; Fares and Kayser, 2011; Lane et al., 2013; Sinclair et al., 2014). It is possible that previous studies measuring the effect of CMR on skill-specific sport performance have failed to reach statistical significance because the measurements were not sensitive enough to detect the small effect of CMR. The reported performance effect of CMR on performance is between 1.5 and 3.5 %, therefore the measurements used must be sensitive at this level of precision. In order to overcome this limitation, the present study reduced the target size to a standardised circle (8.9 cm diameter) during the lunge test, even though the whole body is a valid target during epee fencing. Such measures should be taken in to consideration in future work across other sports.

The present study included a fasting period (> 4 hours) prior to testing which is consistent with previous studies reporting a positive effect of CMR on exercise performance (Carter Jeukendrup and Jones, 2004, Chambers, Bridge and Jones, 2009., Rollo et al., 2008). Overnight fasting increases the cortical response to CHO in a number of brain regions, including the ventral striatum (Haase et al., 2009). However, Beelen et al. (2009) suggested overnight fasting reduces the validity of the results because in a practical setting athletes typically ingest a high-CHO meal 2 hours prior to competition. More specifically Beelen et al. (2009) found that CMR did not significantly affect performance when participants ingested a High-CHO breakfast prior to testing. However, Fares and

Kayser (2011) and Lane et al. (2013) have reported a significant increase in TT performance when participants' mouth rinsed a CHO solution irrespective of nutritional status. Addressing these divergent findings, future work might consider whether the observed improvements in accuracy observed are retained when participants are fed; a condition more closely reflecting a real-life competitive sports setting.

The movements within fencing require athletes to co-ordinate their upper and lower limbs in order to react to the information conveyed by their opponent. Fencing coaches have identified the speed of fencers' movements in response to their opponents' action as crucial for success (Roi and Bianchedi, 2008). Thus, cognitive speed may also be important. The present study did not find a significant effect of CMR on reaction time to congruent or incongruent stimuli, which would indicate faster cognitive processing. There are a number of possible explanations. Firstly our results could indicate that CMR alone does not affect cognitive function. The findings of the present study are consistent with De Pauw et al. (2015) who also found mouth rinsing MALT did not significantly affect reaction time despite increasing activation within the orbitofrontal cortex. Future work might consider whether the type of CHO being rinsed (glucose and MALT) differentially affects cognition. It is also possible the extent of fatigue induced by the fencing protocol was not adequate to establish a cognitive performance effect of CMR, although the protocol was successful at fatiguing the fencers to a certain level. A performance effect may be observed during the latter stages of competition under conditions of heightened or prolonged fatigue, but it is also possible that fatigue masked any effects on cognitive performance. Furthermore, we measured one test of cognitive performance and it is possible that CMR affects other cognitive processes more strongly. All these should be followed up by further research.

The findings of the present study are important within a practical setting. Looking at the individual results, 7 of the 9 participants' lunge test accuracy improved post protocol in the MALT condition. Furthermore accuracy improved 7.7 %, which may translate in to a significant increment in terms of a tangible performance gain. Previous work by Bottoms et al. (2009) observed on average at least one lunge was performed by a fencer per point scored in a fight. Therefore, the improvement observed would equate to 1 more successful hit in a 15 hit fight, which over the course of a competition would equal a total of 12 more successful hits. In comparison, accuracy decreased by 3.3 % during PLAC. A significantly higher number of lunges was observed post fatigue protocol in the PLAC condition, however the participants' accuracy suffered. During a typical fencing competition every lunge leaves the fencer susceptible to a counter attack from their opponent, therefore it is imperative to be as accurate as possible in order to be successful. In addition, as can be seen in the methods, there was a large variation in age of the participants who participated in the study and thus a large variation in fencing experience. However, there was no discernible trend for age when it came to lunge accuracy performance, suggesting age has not impacted the results.

The practical implications for fencing are that rinsing the mouth with a MALT solution during rest periods between fights could be utilised as a strategy to improve accuracy, especially in the latter elimination rounds of the competition where the onset of central fatigue is likely to occur. Furthermore, from a practical standpoint, CMR has the benefit of providing a nutritional strategy for athletes who experience gastrointestinal (GI) discomfort or for athletes following a calorie-restricted diet. GI distress is commonplace amongst athletes with an estimated 20-50 % experiencing symptoms during a sporting event (Stuempfle & Hoffman, 2015; van Nieuwenhoven, Brouns, & Brummer, 2004). The consequences include nausea, heartburn, vomiting, abdominal cramps, bloating and diarrhoea (Peters et al., 1995), symptoms which will all impair sporting performance. One reason athletes experience GI discomfort during sport is due to high Carbohydrate (CHO) ingestion. In conclusion rinsing the mouth with a carbohydrate (CHO) solution before expectorating improves skill-specific fencing performance, but not cognitive function, following a simulated bout of fatigue inducing fencing.

References

Beaven, C. M., Maulder, P., Pooley, A., Kilduff, L., & Cook, C. (2013). Effects of caffeine and carbohydrate mouth rinses on repeated sprint performance. *Appl Physiol Nutr Metab, 38*(6), 633-637. doi:10.1139/apnm-2012-0333

Beelen, M., Berghuis, J., Bonaparte, B., Ballak, S. B., Jeukendrup, A. E., and van Loon, L. J. (2009) ‘Carbohydrate mouth rinsing in the fed state: lack of enhancement of time-trial performance’, *International Journal of Sport Nutrition and Exercise Metabolism*, 19(4), pp. 400-409.

Black, K, Skidmore, P, & Brown, R 2012, 'Energy Intakes of Ultraendurance Cyclists During Competition, an Observational Study', *International Journal Of Sport Nutrition & Exercise Metabolism*, 22(1), pp. 19-23.

Borg, G. A., (1982) ‘Psychophysical bases of perceived exertion’, *Med Sci Sport Exerc,* 14, pp. 377-381.

Bottoms, L., Greenhalgh, A. and Gregory, K. (2013) ‘The effect of caffeine ingestion on skill maintenance and fatigue in epee fencers’, Journal of Sports Sciences, 31(10), pp. 1091–1099. doi: 10.1080/02640414.2013.764466.

Bottoms, L. M., Hunter, A. M. and Galloway, S. D. R. (2006) ‘Effects of carbohydrate ingestion on skill maintenance in squash players’, *European Journal of Sport Science*, 6(3), pp. 187–195. doi: 10.1080/17461390600804455.

Bottoms, L., Rome, P., Gregory, K., and Price, M. (2009) 'Development of a lab based fencing protocol for male epee fencers', *Journal of Sport Sciences,* 27(S2), pp. 133-135.

Burke, L. M., Cox, G. R., Cummings, N. K., and Desbrow, B. (2001) 'Guidelines for daily carbohydrate intake: do athletes achieve them', *Journal of Sports Medicine,* 31(4), pp. 267–299.

Carter, J. M., Jeukendrup, A. E. and Jones, D. A. (2004) 'The effect of carbohydrate mouth rinse on 1-h cycle time trial performance', *Medicine & Science in Sports & Exercise*, pp. 2107–2111. doi: 10.1249/01.mss.0000147585.65709.6f.

Carter, J. M., Jeukendrup, A. E., Mann, C. H. and Jones, D. A. (2004a) 'The effect of glucose infusion on glucose Kinetics during a 1-h time trial', *Medicine & Science in Sports & Exercise*, 36(9), pp. 1543–1550. doi: 10.1249/01.mss.0000139892.69410.d8.

Cermak, N. M. and van Loon, L. J. (2013) 'The use of Carbohydrates during exercise as an Ergogenic aid', *Journal of Sports Medicine*, 43(11), pp. 1139–1155. doi: 10.1007/s40279-013-0079-0.

Chambers, E. S., Bridge, M. W. and Jones, D. A. (2009) 'Carbohydrate sensing in the human mouth: Effects on exercise performance and brain activity', *The Journal of Physiology*, 587(8), pp. 1779–1794. doi: 10.1113/jphysiol.2008.164285.

Clarke, N. D., Kornilios, E., and Richardson, D. L. (2015) 'Carbohydrate and Caffeine Mouth Rinses Do Not Affect Maximum Strength and Muscular Endurance Performance', *Journal of Strength and Conditioning Research,* 29(10), pp. 2926-2931. doi: 10.1519/JSC.0000000000000945.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. Hillsdale, New York: Erlbaum

Davey, P. R., Thorpe, R. D. and Williams, C. (2002) 'Fatigue decreases skilled tennis performance', *Journal of Sports Sciences*, 20(4), pp. 311–318. doi: 10.1080/026404102753576080.

De Pauw, K., Roelands, B., Knaepen, K., Polfliet, M., Stiens, J. and Meeusen, R. (2015) 'Effects of caffeine and maltodextrin mouth rinsing on P300, brain imaging, and cognitive performance', *Journal of Applied Physiology*, 118(6), pp. 776–782. doi: 10.1152/japplphysiol.01050.2014.

Dorling, J. L., & Earnest, C. P. (2013). Effect of carbohydrate mouth rinsing on multiple sprint performance. *J Int Soc Sports Nutr, 10*(1), 41. doi:10.1186/1550-2783-10-41

Fares, E. J. M. and Kayser, B. (2011) 'Carbohydrate mouth rinse effects on exercise capacity in Pre- and Postprandial states', *Journal of Nutrition and Metabolism*, 2011, pp. 1–6. doi: 10.1155/2011/385962.

Haase, L., Cerf-Ducastel, B. and Murphy, C. (2009) 'Cortical activation in response to pure taste stimuli during the physiological states of hunger and satiety', *NeuroImage*, 44(3), pp. 1008–1021. doi: 10.1016/j.neuroimage.2008.09.044.

Hargreaves, M., Hawley, J. A. and Jeukendrup, A. (2004) 'Pre-exercise carbohydrate and fat ingestion: Effects on metabolism and performance', *Journal of Sports Sciences*, 22(1), pp. 31–38. doi: 10.1080/0264041031000140536.

Hornery, D. J., Farrow, D., Mujika, I. and Young, W. (2007) 'Fatigue in tennis', *Sports Medicine*, 37(3), pp. 199–212. doi: 10.2165/00007256-200737030-00002.

Jeffers, R., Shave, R., Ross, E., Stevenson, E. J. and Goodall, S. (2015) 'The effect of a carbohydrate mouth-rinse on neuromuscular fatigue following cycling exercise', *Applied*

Journal of Physiology, Nutrition, and Metabolism, 40(6), pp.557-64 doi: 10.1139/apnm-2014-0393.

Jeukendrup, A., Brouns, F., Wagenmakers, A. and Saris, W. (1997) ‘Carbohydrate-Electrolyte feedings improve 1 h time trial cycling performance’, *International Journal of Sports Medicine*, 18(02), pp. 125–129. doi: 10.1055/s-2007-972607.

Lane, S. C., Bird, S. R., Burke, L. M. and Hawley, J. A. (2013) ‘Effect of a carbohydrate mouth rinse on simulated cycling time-trial performance commenced in a fed or fasted state’, *Applied Physiology, Nutrition, and Metabolism*, 38(2), pp. 134–139. doi: 10.1139/apnm-2012-0300.

Li, J.X., So, R. C. H., and Yuan, Y.W.I. (1999) ‘Muscle strain and cardio-vascular stress in fencing competition. Proceedings of the 5th IOC World Congress on Sport Sciences; Oct 31-Nov 5, Sydney: 222.

McRae, K. A., and Galloway, S. D. (2012) ‘Carbohydrate-electrolyte drink ingestion and skill performance during and after 2 hr of indoor tennis match play’, *International Journal of Sport Nutrition and Exercise Metabolism*, 21(1), pp. 38-46.

Meeusen, R. (2014) ‘Exercise, nutrition and the brain’, *Sports Medicine*, 44(1), pp. 47–56. doi: 10.1007/s40279-014-0150-5.

Peters, H. P. F., Akkermans, L. M. A., Bol, E. and Mosterd, W. L. (1995) ‘Gastrointestinal symptoms during exercise’, *Sports Medicine*, 20(2), pp. 65–76. doi: 10.2165/00007256-199520020-00002.

Phillips, S. M., Findlay, S., Kavaliauskas, M., and Grant, M. C. (2014) ‘The influence of serial carbohydrate mouth rinsing on power output during a cycle sprint’ *Journal of Sport Sciences and Medicine,* 13, pp. 252-258.

Přibyslavská, V., Scudamore, E. M., Johnson, S. L., Green, J. M., Stevenson Wilcoxson, M. C., Lowe, J. B. and O’Neal, E. K. (2015) ‘Influence of carbohydrate mouth rinsing on running and jumping performance during early morning soccer scrimmaging’, *European Journal of Sport Science*, pp. 1–7. doi: 10.1080/17461391.2015.1020345.

Roi, G., and Bianchedi, D. (2008) ‘The science of fencing: Implications for performance and injury prevention’, *Sports Medicine,* 38(6), pp. 465-481.

Rollo, I., Cole, M., Miller, R. and Williams, C. (2010) ‘Influence of mouth rinsing a carbohydrate solution on 1-h running performance’, *Medicine & Science in Sports & Exercise*, 42(4), pp. 798–804. doi: 10.1249/mss.0b013e3181bac6e4.

Rollo, I., Williams, C., Gant, N., and Nute, M. (2008) ‘The influence of carbohydrate mouth rinse on self-selected speeds during a 30-min treadmill run’ *International Journal of Sport Nutrition and Exercise Metabolism*, 18, pp. 585-600.

Royal, K. A., Farrow, D., Mujika, I., Halson, S. L., Pyne, D. and Abernethy, B. (2006) ‘The effects of fatigue on decision making and shooting skill performance in water polo players’, *Journal of Sports Sciences*, 24(8), pp. 807–815. doi: 10.1080/02640410500188928.

Sanders, M. A., Shirk, S. D., Burgin, C. J. and Martin, L. L. (2012) ‘The gargle effect: Rinsing the mouth with glucose enhances self-control’, *Psychological Science*, 23(12), pp. 1470–1472. doi: 10.1177/0956797612450034.

Sinclair, J., Bottoms, L., Flynn, C., Bradley, E., Alexander, G., McCullagh, S., Finn, T. and Hurst, H. T. (2014) ‘The effect of different durations of carbohydrate mouth rinse on cycling performance’, *European Journal of Sport Science*, 14(3), pp. 259–264. doi: 10.1080/17461391.2013.785599.

Stuempfle, K. J. and Hoffman, M. D. (2015) ‘Gastrointestinal distress is common during a 161-km ultramarathon’, *Journal of Sports Sciences*, 33(17), pp. 1814–1821. doi: 10.1080/02640414.2015.1012104.

Turner, C. E., Byblow, W. D., Stinear, C. M., & Gant, N. (2014). Carbohydrate in the mouth enhances activation of brain circuitry involved in motor performance and sensory perception. *Appetite, 80*, 212-219. doi:10.1016/j.appet.2014.05.020

van Nieuwenhoven, M. A., Brouns, F., & Brummer, R. J. M. (2004). Gastrointestinal profile of symptomatic athletes at rest and during physical exercise. *European Journal of Applied Physiology, 91*(4), 429-434. doi:10.1007/s00421-003-1007-z

Whitham, M. and McKinney, J. (2007) 'Effect of a carbohydrate mouthwash on running time-trial performance', *Journal of Sports Sciences*, 25(12), pp. 1385–1392. doi: 10.1080/02640410601113676.

Tables:

Table 1. Mean (± *s*) RPE (Borg Scale) and heart rate across all fights for PLAC and MALT conditions for sword arm, legs and overall.

	RPE_{arm}	RPE_{legs}	$RPE_{overall}$	Heart Rate (beats · min^{-1})
PLAC	10.9 (±2.3)	13.0 (± 2.4)	13.4 (±1.4)	158 (± 7)
MALT	10.9 (±2.5)	12.6 (± 2.8)	12.6 (± 1.8)	159 (± 4)

Table 2. The mean (± *s*) hits on target (%) for PLAC and Malt.

	Pre-protocol (%)	Post-protocol (%)
PLAC	82.1 (± 8.8)	78.8 (± 6.4)
MALT	81.2 (±8.3)	87.6 (± 9.4)

List of Figures:

Figure 1. Mean (± *s*) a) blood glucose and blood lactate (b) concentrations during exercise for both PLAC and MALT. *Denotes significant increase in blood lactate concentration between resting and pre-protocol.

Figure 2. Mean (± *s*) pre- and post-fatiguing protocol congruent (C) and incongruent (I) response times to the Stroop test for both placebo (PLAC) and maltodextrin (MALT).