ABSTRACT

Dawn L. Anderson and Matt Laurent, Committee Co-Chairs

Statement of Problem: The development of fatigue is influenced by simply rinsing the mouth with a carbohydrate solution and is related to telo-anticipation. However, the extent to elicit a strong enough ergogenic response to mitigate fatigue in intense exercise lasting less than 60 minutes is quite limited. Therefore, further investigations are needed to determine an ideal strategy for rinsing carbohydrates to improve short duration and intense exercise performance is needed.

Method: Sixteen sprint-trained participants (8=male and 8=female) performed a series of repeated sprint tests under two different conditions in a counterbalanced order; one where they were administered a carbohydrate solution that was rinsed for five seconds and another condition in which the beverage was rinsed incrementally (five, 10, and 15 seconds). Each testing session consisted of three repeated sprint exercise sets (RSE) on a non-motorized treadmill with seven minutes of recovery between sets. Peak speed, average speed, rating of perceived exertion (RPE), perceived recovery status (PRS), perceived activation (FA) were all measured. Approximately 15 minutes following the final sprint, participants provided a session rating of perceived exertion (S-RPE) to rate the global difficulty of the session.

Results: Results from the analyses revealed no significant differences between conditions on peak (p = 0.179) or average (p = 0.414) sprint performance. Nor was there any difference between male and female sprint performance. Furthermore, there were no perceptual (PRS, RPE, FA) or metabolic (lactate) differences of fatigue. However, during latter portions of the repeated sprint protocol, average and peak speed of participants showed a trend towards a difference
between both conditions in repeated sprint set 2 (RSE₂) and repeated sprint set 3 (RSE₃). The decrements in sprint performance (p = 0.795) and recovery scores (p = 0.847) were not significantly different between CMR conditions.

**Conclusions:** The administration of carbohydrate mouth rinsing (CMR) with increasing duration did not significantly yield improved average or peak sprint performance as compared to rinsing with a consistent duration. More investigations are needed to help further understand the perceptual responses that relate the central and peripheral integration of fatigue with carbohydrate supplementation with repeated sprints.

**Key words:** Carbohydrate mouth rinsing, sprint, fatigue, intermittent
I wish to dedicate this thesis to my parents, Michael and Barbara Tomko, who have not only been incredibly supportive of me throughout my life, but were also the inspiration for my developed interests and passion through education. Words cannot express my gratitude for all your past and continued love and benevolence throughout the years.
ACKNOWLEDGMENTS

First, I would like to thank Dr. Dawn Anderson, Dr. Matt Laurent, Dr. Adam Fullenkamp, and Carrie Hamady for not only assisting me with this study by being on my committee, but also for adding to my education and growth over the previous years. Their own viewpoints from their respective disciplines were irreplaceable throughout this process.

The assistance provided by all the graduate students during data collection was greatly appreciated. Thanks to Trent Pilmore, who helped ensure participant safety while also keeping me composed during data collection. My appreciation goes to Adam Bialecki for bringing his invaluable attention to detail in the lab and taking on anything that I asked of his with willingness and enthusiasm. I would also like to thank Carmen Young, though words cannot convey how indebted I am to her. I am lucky to have a person as special as her in my life, as I could vent to her, which allowed me to ease the stress and anxiety when things seemed to continually spiral downward. Thank you for keeping me sane and helping with the study.

I would lastly like to thank my mother and father for infusing the character needed to complete a thesis. Thanks to my mother for always cheering me on and expressing to me that I could do anything that I set out to do. Thanks to my father and his encouragement for me to appreciate a process of work and to learn from all, that kept me level-headed through hard times during the process. I could not have done any of this without their unending love and reassurance.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER I. INTRODUCTION</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates and Exercise Performance</td>
<td>1</td>
</tr>
<tr>
<td>Carbohydrate Manipulation</td>
<td>1</td>
</tr>
<tr>
<td>Glycogen and Fatigue Development</td>
<td>2</td>
</tr>
<tr>
<td>Mechanisms of Fatigue and Carbohydrates</td>
<td>3</td>
</tr>
<tr>
<td>Carbohydrate Mouth Rinsing (CMR)</td>
<td>4</td>
</tr>
<tr>
<td>Potential Benefits of CMR</td>
<td>5</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>6</td>
</tr>
<tr>
<td>Significance of the Study</td>
<td>6</td>
</tr>
<tr>
<td>Objectives of the Study</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAPTER II. REVIEW OF LITERATURE</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overview</td>
<td>8</td>
</tr>
<tr>
<td>Fatigue</td>
<td>9</td>
</tr>
<tr>
<td>Peripheral</td>
<td>9</td>
</tr>
<tr>
<td>Central</td>
<td>10</td>
</tr>
<tr>
<td>Repeated Sprint Ability</td>
<td>11</td>
</tr>
<tr>
<td>Exercise Mode</td>
<td>11</td>
</tr>
<tr>
<td>Sprint Duration and Recovery</td>
<td>12</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Sex Differences in Exercise Performance</td>
<td>14</td>
</tr>
<tr>
<td>Motor Unit Function</td>
<td>15</td>
</tr>
<tr>
<td>Facilitation of Motor Unit Output</td>
<td>15</td>
</tr>
<tr>
<td>Corticomotor Excitability</td>
<td>15</td>
</tr>
<tr>
<td>Maximum Voluntary Contraction</td>
<td>16</td>
</tr>
<tr>
<td>Concentration, Duration, and Frequency of CMR</td>
<td>17</td>
</tr>
<tr>
<td>Concentration</td>
<td>17</td>
</tr>
<tr>
<td>Duration</td>
<td>17</td>
</tr>
<tr>
<td>Frequency</td>
<td>18</td>
</tr>
<tr>
<td>Nutritional Status</td>
<td>19</td>
</tr>
<tr>
<td>Glycogen Availability</td>
<td>20</td>
</tr>
<tr>
<td>Sleep low, Train-low</td>
<td>21</td>
</tr>
<tr>
<td>Glycogen Reduced State</td>
<td>21</td>
</tr>
<tr>
<td>Summary</td>
<td>22</td>
</tr>
<tr>
<td>CHAPTER III. METHODS</td>
<td>24</td>
</tr>
<tr>
<td>Overall Design</td>
<td>24</td>
</tr>
<tr>
<td>Participants</td>
<td>24</td>
</tr>
<tr>
<td>Participant Recruitment</td>
<td>25</td>
</tr>
<tr>
<td>Physiological Measures</td>
<td>26</td>
</tr>
<tr>
<td>Body Height, Mass, and Percent Body Fat</td>
<td>26</td>
</tr>
</tbody>
</table>
CHAPTER V. DISCUSSION

Overview

Fatigue Development From Repeated Sprints
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Descriptive characteristics of the participants</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>Standardized warm-up protocol</td>
<td>30</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Schematic illustration of repeated sprint protocol for each given condition excluding rinse duration</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Average speed achieved during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16)</td>
<td>34</td>
</tr>
<tr>
<td>3</td>
<td>Peak speed achieved during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16)</td>
<td>34</td>
</tr>
<tr>
<td>4</td>
<td>Average speed achieved during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants</td>
<td>35</td>
</tr>
<tr>
<td>5</td>
<td>Peak speed achieved during each RSE under set condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants</td>
<td>36</td>
</tr>
<tr>
<td>6</td>
<td>Mean rating of perceived exertion reported during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16)</td>
<td>37</td>
</tr>
<tr>
<td>7</td>
<td>Mean perceived recovery reported after each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16)</td>
<td>37</td>
</tr>
<tr>
<td>8</td>
<td>Mean perceived recovery reported after each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16)</td>
<td>37</td>
</tr>
</tbody>
</table>
five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants) ........................................ 38
9 Mean rating of perceived exertion reported during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants) ........... 39
10 Session rating of perceived exertion reported after completion of testing between females (N=8) and males (N=8) under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16) 39
11 Blood lactate levels immediately following each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16) ................................................................. 40
12 Blood lactate levels immediately following each RSE set during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male .... 41
13 Mean rating of perceived activation reported during each RSE set under condition 1 and condition 2 (N = 16). Condition 1 is the five second rinse strategy and condition 2 is the incremental rinse strategy (five, 10 and 15 seconds) ......................... 41
14 Mean rating of perceived activation reported during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants.............. 42
15 The speed decrement that occurred during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 Second rinse strategy) (N=16) ................................................................. 43
The speed decrement that occurred during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants.............

The recovery of speed that occurred during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16) ................................................... 45

The recovery of speed that occurred during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants............. 46
CHAPTER I.
INTRODUCTION
Carbohydrates and Exercise Performance

The established role that carbohydrate availability has in modulating fatigue is paramount for developing and periodizing nutrition to maximize performance. The delivery of additional carbohydrates into the active musculature is extremely important because it improves the body’s ability to fuel exercise. A low availability of carbohydrates limits performance during prolonged exercise or during high intensity types of exercise (1). Sparing and restoring glycogen content during exercise is vital for maintaining optimal performance and achieving early recovery (2). Strategies have been developed that manipulate the timing, pattern, quality, and type of carbohydrate consumed to achieve maximal glycogen storage (1).

Maximal glycogen storage and high carbohydrate availability have been a major focus to improve exercise performance (3,4). However, recent investigations with low carbohydrate availability has also shown potential benefits for adaptations related to performance (5–9). Purposely depleting glycogen and training with low glycogen content has been implemented as early as the 1960s (10). Training with low glycogen content over a period results in an elevation of muscle glycogen that is above relatively normal levels in individuals. Thus, methods to maximize muscle glycogen content in individuals to improve exercise performance can be achieved through an increase and/or decrease in carbohydrate intake.

Carbohydrate Manipulation

Carbohydrate intake can be changed relative to the exercise demand, hours, or number of days prior to a performing in a competition. This allows an athlete to compete with adequate fuel
stores that will help offset fuel costs during the event. Events that are longer (>90 minutes) benefit more than events shorter (< 90 minutes) from strategies that increase glycogen content (11). Increasing glycogen content prior to an event has been termed “carbohydrate loading” and can be achieved through diet and training (5). The basic framework for carbohydrate loading requires an athlete to participate in a period of training that depletes glycogen and reduces carbohydrate availability. Dietary methods must then be incorporated to help replenish glycogen and increase carbohydrate availability (1). This framework can be changed to load carbohydrates in a shorter time without dietary intervention and rather adjust training variables like work to rest ratios. For example, some studies (12,13) have shown that carbohydrate loading can increase glycogen concentrations without a dietary depletion phase and result in increased glycogen content from a shorter time period (14). However, there are still questions about carbohydrate manipulation and its relation to the total glycogen content in the muscle and liver. McInerney et al (15) showed that elevations in muscle glycogen content were unable to occur beyond a 48 hour period of a carbohydrate loading.

**Glycogen and Fatigue Development**

It has been argued that carbohydrate intake may be the single largest determinant for maximizing performance during prolonged endurance events (>60 minutes) (16). Carbohydrate intake limits the onset of fatigue in multiple sporting events (17). However, fatigue is complex and has been broadly defined as ‘the failure to maintain a required or expected power’ (18). The mechanisms by which some individual fatigues involve multiple components and leads to varying results across different types and durations of sports. Glycogen depletion in an individual reduces the muscle’s ability to contract and do work. Furthermore, an imbalance of adenosine triphosphate (ATP) formation impairs the ability for muscle to generate a required force (19).
The duration of the event influences the fatigue pattern that develops; therefore, carbohydrate supplementation may not be as large of a determinant in a sporting event that is less than 60 minutes as compared to an event more than 60 minutes. For example, intermittent sports require short immediate bursts of high intensity exercise from the athlete, but only last one to two hours (1). These high intensity bursts require sport specific skill and cognitive task over that period of time (20). Furthermore, the repeated high intensity bursts are commonly associated with inadequate recovery time. Thus, recovery time has a significant role in the extent carbohydrates (CHO) may help in sport specific skills and cognitive tasks during exercise performance (2).

**Mechanisms of Fatigue and Carbohydrates**

From the multitude of mechanisms that may be responsible for the onset of fatigue, two have emerged to help explain why carbohydrates improve performance. The first mechanism involves the immediate contribution exogenous CHO oxidation has during muscle glycogen limiting exercise (i.e. repeated sprints). Anaerobic glycolysis supplies approximately 40% of the total energy during a six second sprint (21). However, a significant decrease in ATP production from glycolysis occurs from the first to last sprint in a repeated sprint set (21). Exogenous CHO intake spares the glycogen content used in anaerobic glycolysis, allowing for better performance from the first to last sprint in each repeated sprint set. The second mechanism suggests a cognitive stimulation of the central nervous system via oral exposure of CHO. During shorter exercise durations, muscle glycogen may not be as limiting, and sparing of muscle glycogen is not as much of a priority (16). Because fatigue can manifest centrally and/or peripherally, the ergogenic effect from carbohydrates benefit both localities at different points as fatigue develops. For example, an individual exercising for a shorter period may initially benefit from
carbohydrates via central mediation of fatigue, and then later the carbohydrate supplementation may mediate peripheral response(s) as the exercise period lengthens. Thus, investigating exercise less than 60 minutes is just as critical as investigations with exercise lasting longer than 60 minutes.

**Carbohydrate Mouth Rinsing (CMR)**

Studies have shown the impact that carbohydrate ingestion has on endurance performance (22,23). However, the ergogenic effect of CHO on exercise less than 60 minutes has been less clear. Carter et. al (24) pioneered a study to evaluate the impact CHO may have on performance in exercise that lasts less than 60 minutes. He asked nine cyclists to perform two time trials, requiring participants to complete a set amount of work as fast as possible. The cyclists were instructed to rinse their mouth with a 6.4% maltodextrin or with water (placebo) every 12.5 percent of the exercise completed (8 times). Frequent rinsing of the CHO resulted in improved time trial performance as compared to water rinsing (24). These findings suggested that the improved performance from CMR during high intensity exercise may not be related to actual CHO ingestion. Furthermore, the findings allude to the role both blood glucose and muscle glycogen have as limiting factors in exercise lasting only 60 minutes or less (16).

Mcconnell et.al (25) found that only a small amount (26%) of ingested CHO reaches the periphery of the body during high intensity exercise. Understanding only a small amount about muscle glycogen and blood glucose have in energy production during short duration exercise has led to numerous studies investigating CMR and potential mechanisms behind performance enhancement (24,26–37).
Potential Benefits of CMR

Although the ergogenic effect from CMR seems trivial in some studies (27,32,37), the majority of studies on CMR show some degree of benefit on performance. The ergogenic effect of CMR is linked to a central component of fatigue. However, the benefits of delaying the onset of fatigue via ingestion as compared to rinsing carbohydrates seem to have similar ergogenic responses in performance (33,38). CMR may be a useful tool to incorporate into individual training and nutritional periodization plans to achieve specific performance goals.

CMR can be effective in two different training scenarios for athletes. One scenario involves exercise comfortability. Carbohydrate consumption has been linked to gastrointestinal (GI) disturbance, which has shown to have negative effects on performance outcomes due to the GI symptoms an athlete experiences (39). CMR has similar performance benefits from CHO ingestion and can dramatically reduce GI distress experienced by some athletes (40). The other circumstance involves strategically consuming CHO through training regimens. A more recent strategy of “train low, compete high” (41) that can incorporate CMR, results in adaptations that may improve performance (42).

Rinsing the mouth with a carbohydrate solution influences central fatigue in repeated sprint exercise (43). The influential mechanism is likely related to brain regions that indicate arousal and motivation, which may alter the feed-forward model of fatigue (44). Corticomotor output can be altered through the CNS simply sensing CHO from receptors in the mouth, which activate brain regions in ways that influence fatigue mediation (45). For example, changes in ratings of perceived exertion (RPE) could be impacted by the central link found with carbohydrate mouth rinsing (CMR) during time trial performance; this has been closely linked with self-pacing techniques (46).
Statement of the Problem

CMR before or during exercise can enhance exercise performance. Rinse time (needed to stimulate oral receptors), rinse amount (concentration), and rinse composition (glucose, fructose, and maltodextrins) all may influence the ergogenic effect (47). Exercise performance can be enhanced or maintained with CMR through a reduction of fatigue and/or enhancement of recovery (48). Both the central and peripheral aspects of the nervous system regulate response to fatigue (49). Stimulating the oral receptors with carbohydrates helps generate a central response that helps attenuate fatigue (50). In particular, aerobic dominant exercise (exercise longer than 60 min) benefits from CMR (16). A potential drawback is that the mouth rinse may not be powerful enough to attenuate “stronger” signals of fatigue (signals that come from longer, more intense exercise periods). Sports that require a great demand of central nervous system (CNS) function (high levels of activation for a short period of time, e.g. sprinting) may benefit from CMR. Although it seems competition benefits may be difficult to determine conclusively, a training benefit from CMR could still be helpful in sport performance. Literature is limited regarding a ergogenic effect that is strong enough to impact fatigue in intense exercise lasting less than 60 minutes. Developing an ideal CMR strategy to improve short duration and intense exercise performance has yet to be fully determined.

Significance of the Study

Performance in intermittent sports is largely dependent on the combination of anaerobic and aerobic energy systems. These systems utilize muscle glycogen and/or blood glucose for energy production. The ingestion of CHO provides an ergogenic effect that influences the mechanisms involved in energy production (25). The amount, timing, and type of CHO and the timing of an athlete’s last meal, all impact the ergogenic effect in exercise performance (47). The
practicality of this carbohydrate mouth rinsing strategy depends primarily on its level of enhancement in performance across the type and the duration of the sport. A “train-low, compete-high” strategy has emerged to improve adaptations that impacts overall performance (42). It requires athletes to perform in periods with low energy availability. It is worth noting that the majority of studies have been conducted using a non-weight bearing exercise (cycling) and are longer in exercise duration (24,27–31,33). There is a lack of evidence using CMR in weight bearing exercise (running) and shorter exercise durations. Additionally, evidence regarding CMR impact on performance in female athletes is sparse with only a few studies containing female athletes (51–53). Therefore, it is important to further investigate ways to maximize CMR as a potential strategy improve performance in short duration exercise that involves running, and determine whether female and male athletes’ performance are influenced differently.

Objectives of the Study

The objectives of this study are to:

1) Determine the impact of CMR duration has on peak and mean speed output during repeated sprints.

2) Determine if a dose-response relationship between rinse duration and repeated sprint performances exists.

3) Determine the impact CMR has between sexes and performance outcomes.
CHAPTER II.
REVIEW OF THE LITERATURE

Overview

The ingestion of carbohydrate (CHO) beverages by individuals before and during all modes of exercise can delay fatigue and improve performance (34). There have been negligible performance differences in some studies that compare carbohydrate mouth rinsing (CMR) to CHO ingestion, regardless of exercise mode (54,55). However, some researchers have found that CHO ingestion appears to improve performance a greater amount when the individual’s exercise is longer than 30 minutes (16). Exercise lasting longer than two hours (i.e. marathons) benefits from CHO ingestion (56). Shorter, intermittent exercise may benefit more from CMR than CHO ingestion.

There have been a variety of CMR strategies with different exercise modes that demonstrate the effects that CMR has on exercise performance; however, only a few studies involved participants sprinting (weight bearing) as compared to participants cycling (non-weight bearing) (34,35,37,57). These CMR strategies involve protocols that account for both physiological and psychological changes during exercise. Several researchers have implemented exercise protocols, which allow participants to self-select their pace in order to compare the total distance covered with and without CMR (34,36). Other research has implemented cycle sprints to assess power output (58). It is important to consider both self-pacing protocols and sprinting protocols in individuals who participant in intermittent sports. Short sprints followed by brief periods of rest is a performance pattern consistently seen in intermittent sports (20). Thus, investigating the effects CMR may have on changes in multiple sprints may provide more a practical usage for CMR in sports like soccer, rugby, field hockey, etc.
Fatigue

Fatigue is defined as the amount of force developed that is less than expected as consequence of muscle activation (59). The origin of fatigue changes during exercise performance. The development of fatigue occurs as a progressive decline in power output within a duration of the intertwined recovery periods (60). Fatigue manifestation during repeated sprints is primarily dependent upon three variables: number of repetitions, sprint duration, and recovery pattern (48). Altering the repetitions, duration of the sprint, and the recovery period will influence muscular factors, such as muscle excitability, energy availability, and neural factors, such as neural drive to activate musculature (48). The influenced muscular factors are commonly categorized as peripheral fatigue, while the influenced neural drive has been categorized as central fatigue. Central fatigue is associated with feelings of tiredness, lethargy and pain (49). The ability to sprint begins with voluntary effort, thus a decision to work harder and stop completely begins strictly in the central nervous system and supports the feed-forward model (61). Full voluntary muscle contraction may require more than just central input, as the size of muscle groups and exercise intensity involve different integration patterns from both peripheral and central systems (61). Hureau et. al (62) investigated the development of neuromuscular fatigue in all-out-repeated-sprints. Findings from the study support the idea of “central command theory,” and the authors concluded that power output is limited in order to prevent excessive peripheral fatigue (62). These findings emphasize a central and peripheral integration that can contribute to the change in exercise performance.

**Peripheral**

Peripheral skeletal muscle fatigue involves processes near the neuromuscular junction and can occur in addition to changes in central motor output (63). During repeated bouts of
maximal work, the intramuscular environment changes and influences the ability to generate force. Three causative factors have been suggested for muscular fatigue. One factor is the reduced availability of ATP for actin-myosin coupling, \(\text{Na}^+/\text{K}^+\) pumping, and \(\text{Ca}^{2+}\) uptake within sarcoplasmic reticulum (60). Another factor involves metabolic by-products (lactate, inorganic phosphates, hypoxanthine and hydrogen ions) inhibiting any of the three physiological scenarios mentioned in factor one (60). Thirdly, changes in the excitation-contraction coupling (ECC) from the action potential to \(\text{Ca}^{2+}\) release from the sarcoplasmic reticulum could be a causative factor (64). It is important to note, that oxygen sufficiency may influence the metabolic by-product concentrations, like inorganic phosphates, within the skeletal muscle (65). A reduced oxygen sufficiency within the muscle results in an increased rate of fatigue (66). All these factors can contribute to the development of peripheral fatigue. Thus, fatigue is likely to controlled through a more complex integration of all these factors and systems.

**Central**

Central command is perceived as a sense of effort, and as the effort and other sensations like muscle pain become more than tolerable, then exercise is terminated voluntarily (61). Maximum voluntary contraction does not always lead to full activation of muscles to generate an increase in force (61). A change or reduction in recruitment patterns of muscle fibers is dependent upon central nervous system input, thus a decrease in force could occur without metabolic perturbations. The feed-forward model supports the executive role the CNS has in dynamic exercise. It is explained that the “central governor” would receive inputs from various systems that are all related to the dynamic exercise occurring, and integrate all of the information to base a decision on whether to stop the effort if the input goes beyond a specific threshold (61). The threshold represents a prevention of recruitment in muscle mass beyond
levels of exercise duration and intensity that may be damaging to human body (67). It seems that although exercise performance is primarily determined by cardio-respiratory and metabolic by-product tolerance, the central integration of information may determine the final performance outcomes.

Repeated Sprint Ability

Athletes who are engaged in team sports are typically required to produce maximal or near maximal effort. Brief recovery intervals occur within these efforts over a period that is about one hour or longer. Repeated sprints incorporate these maximal efforts and brief recovery periods. Improving an individual’s repeated sprint ability should result in a greater team-sport physical performance. However, it is important to distinguish the difference between intermittent-sprint exercise and repeated sprint exercise as one exercise may be more appropriate for replicating sport specificity. Intermittent-sprint exercise has short-duration sprints with recovery periods in-between that are long enough for complete recovery in performance (68). Repeated sprint-exercise also has short-duration sprints, but the recovery periods in-between are much more brief (≤60 seconds) (48). The main difference is that repeated sprint-exercise has a performance decrement, and intermittent-sprint exercise has almost no performance decrement (69). This difference is important to consider when looking at different components (central and/or peripheral) of fatigue.

Exercise Mode

The severity of the fatigue experienced by an individual is directly influenced by the task being performed (70). Cycling (non-weight bearing) and running (weight-bearing) have different patterns of fatigue development (48). The type of resistive load (i.e. wind, mechanical, or
surface) is a factor that would influence fatigue differently between running and cycling (48). Ventilatory responses differ between modes as well, where cycling to volitional exhaustion shows a more altered ventilatory response compared to running to volitional exhaustion (71). Additionally, a lower cardiac output has been observed in cycling as compared to running, which results in a reduced cardiac filling rate and negatively impacts the venous return (71). The mechanism responsible for venous return is impacted by the central nervous system, thus innervation of the CNS may influence the fatigue pattern between modes (72). Furthermore, there has been an observed decrease in central fatigue and maximal force production in running as compared to cycling (71). Exercise mode is a critical variable to consider when examining fatigue patterns from submaximal and maximal efforts and from short and long duration exercise (48,71).

Sprint Duration and Recovery

A crucial determinant of fatigue during repeated sprint exercise is represented by the initial sprint. Individuals sprinting with a greater initial sprint performance will have more substantial changes in muscle metabolites (i.e. lactate) from the increasing reliance on anaerobic energy systems. These substantial changes affect sprinting performance through changes in muscular contractility and inhibition of ATP from glycolysis. A greater reliance on the phosphagen system and anaerobic glycolysis is related to larger performance decrements. The contribution from both energy systems during repeated sprints is heavily influenced by the duration of the sprints (73).

Phosphocreatine represents an immediate reserve for phosphorylation of ATP. In repeated sprint exercise, a high turnover rate of ATP occurs, thus a recovery time of more than five minutes is necessary in order to completely restore phosphocreatine levels (74). However,
during repeated sprint exercise, recovery times do not exceed 60 seconds; therefore, ATP/phosphocreatine stores may not fully be restored before starting the next bout of exercise (48). Performance is expected to decrease accordingly for each successive sprint during the repeated sprint exercise.

Anaerobic glycolysis helps supply energy during a single sprint, but like the phosphagen system, it declines in ability to help provide ATP as sprints are repeated (48). In sprints lasting less than 10 seconds, a contribution from anaerobic glycolysis occurs as early as two to three seconds (73). Throughout the duration of repeated sprints performed by the individual, the contribution of anaerobic glycolysis becomes less, and a shift to oxidative metabolism occurs (48). This shift can contribute to as much as 40% of total energy supply during repeated sprints and emphasizes the importance of the aerobic capacity of individuals (75). Furthermore, the rate of oxygen and carbon dioxide that is exchanged in the muscle during recovery is a limiting factor in repeated sprint performance (73). Therefore, considering the individual’s aerobic capacity, a minimum recovery time of five minutes between each set is necessary for participants to have adequate anaerobic power and aerobic capacity for repeated sprints (73).

Dorling and Earnest (57) conducted a study that involved eight males to performed three sets intermittent sprint sets and then run the Loughborough Intermittent Shuttle Test (LIST). The authors found no improvement in performance from CMR, but within sprints sets there was a noticeable difference between the first and second sprint (57). There were no significant perceptual and performance changes. This may have been related to other variables such as oral carbohydrate exposure time and participant nutritional state.
Sex Differences in Exercise Performance

Human skeletal muscle fatigue is influenced by the biological sex of the individual in exercise performance (76–78). Both males and females fatigue different according to task specificity, thus exercise mode influences fatigue development between sex (63). From a physiological perspective, females tend to have a greater resistance to fatigue and recover faster than males (76). Body composition can be an obvious characteristic that is observed when comparing females and males. The cross-sectional area of a muscle group is important in providing an mechanical advantage when performing movements that require muscles acting across a joint (63). The mechanical advantage is gained through segment length and fiber distribution type (77). Males have greater segment length and muscle mass, allowing them to develop greater force output than females (63). When comparing males and females it is important to account for this physiological difference by scaling the body size of the sample appropriately.

Differences in neural activation between sexes has been difficult phenomena to explain, with no clear distinction of activation patterns between males and females (63). However, one study has suggested that during high intensity interval exercise, women tend to produce lower relative intensities with respect to velocity, but greater perceptual strain (76). The authors explained that the increased strain, did not require the women to have greater recovery period between bouts (76). Thus, it may be possible that a sex difference exists in feedback in fatigue from central input rather than a peripheral input as fatigue develops during high intensity exercise (i.e. sprinting). Literature has suggested that males experience a greater performance decrement due to a greater reliance on anaerobic glycolysis and females display a greater ability to restore power when sprints are longer with longer recovery periods (79,80). Muscle fatigue
during sprint exercise requires further research about the factors contributing to observed sex differences (63).

**Motor Unit Function**

*Facilitation of Motor Unit Output*

Carbohydrate ingestion benefits the individual the most when exercise is longer than 30 minutes in duration, thus exercise shorter than 30 minutes is less likely to have an improvement in performance (16). The duration of the exercise event is significant because of the time that is needed to absorb carbohydrates to help override any manifestation of fatigue (50). However, carbohydrates trigger a central nervous system response from nutrient-specific receptors in the mouth (81). These responses to CHO presence in the oral cavity modify motor output in muscle function (54). The change in motor output has been linked to the ergogenic effect that CMR has on intermittent performance. The pattern of fatigue in intermittent performance involves a progressive decline in neural drive from a reduced output in the primary motor cortex (82). CMR mediates the progressive decline by activation of orbital frontal cortex and striatum (50). These are brain regions involved with reward and motor control (28).

*Corticomotor Excitability*

Gant et. al (83) conducted a study that investigated whether the presence of carbohydrates in the mouth modified corticomotor excitability and voluntary force production from skeletal muscle. The investigation involved two components; one that tested if carbohydrate ingestion would facilitate corticomotor excitability immediately, and one that tested if CMR (no ingestion) was sufficient to facilitate corticomotor excitability during muscle activation without the presence of fatigue. The findings indicated that the presence of carbohydrates in the mouth facilitated corticomotor output in non-fatigued muscle, supporting the idea that the ergogenic
effect of CHO is not limited to ingestion (83). Turner et. al (84) further investigated motor output facilitation through a three solution design: carbohydrate solutions containing both sweet taste and energy properties, placebo solution (PLA), that had the same taste, but a deficient of energy, and a control that lacked in both sweet taste and energy (84). Turner’s findings further explained the difference seen by Gant et al.(83), suggesting the ergogenic effect as being beneficial regardless of the sweetness of carbohydrates.

*Maximum Voluntary Contraction*

Jeffers et. al (85) conducted a study to look at CMR and its relationship with maximum voluntary contraction. He used a non-sweet maltodextrin solution to test the effects CMR may have on cycling time trial performance and fatigue mechanisms. The study found a slight reduction in fatigue (maximum voluntary contraction) using CMR, but no overall time trial performance improvement. The amount of time some individual rinses carbohydrates is likely to influence the facilitation of motor unit output. Additionally the exercise protocol duration may explain the reduction in global fatigue exhibited by the participants (85).

Turner et. al (84) examined corticomotor output in non-fatigued muscle, while Jensen et. al (45) evaluated maximum voluntary contraction in fatigued muscle, Turner et al. (84) found no change in the rate of decline in fatigue, peak torque production, and torque maintenance when using CMR (45). The lack of change in fatigue decline suggests that fatigue was not primarily facilitated through central mechanisms. It is likely that the mediation of fatigue via central command had little involvement with the attenuation in global fatigue response. The literature investigating muscle contraction and excitability in a fatigued and non-fatigued state suggests other factors that should be considered such as rinse duration, frequency, and contraction.
Concentration, Duration and Frequency of CMR

Concentration

Multiple studies with varying carbohydrate rinse durations, frequencies, and concentrations have shown improvement exercise performance (24,26,29–31,33–36). The concentration of carbohydrates necessary for an improvement in performance tends to fall between six and 10 percent by weight (16). A vast majority of studies have utilized a six percent concentrated solution, while a only a few used a 10 percent concentrated solution (31,56,86,87). Ispoglou et. al (86) conducted a study that evaluated varying concentrations of carbohydrate solutions (4%, 6% and 8%) on cycling time trial performance. Performance improvements were seen compared to the placebo condition, but significant differences were not found when comparing the different CHO solution concentrations. Kulaksız et. al (87) conducted a similar study with different CHO solution concentrations (3%, 6% and 8%). The effect of the CHO solutions was compared after participants completed a cycling time trial. The participants fed or fasted state (10 hours) resulted in no significant differences in exercise performance between different carbohydrate solution concentrations (87). Perhaps performance enhancement depends on the length of time that carbohydrate solution is present within the oral cavity rather than the carbohydrate solution concentration.

Duration

Three studies have involved a design with a carbohydrate mouth rinse duration longer than five seconds (28,29,36). However, none of the studies exceeded a carbohydrate mouth rinsing duration greater than 10 seconds. When Chambers et. al (28) examined the brain activity of different regions from CMR, he instructed participants to rinse with the carbohydrate solution for about 10 seconds. Fares and Kayser (29) designed a study investigating the participants in a
pre- or post-prandial state and the CMR effects on performance. The protocol was less specific in rinsing duration. Participants were required to rinse the carbohydrate solution between five and 10 seconds. Interestingly, both studies found performance benefits when asking participants to rinse carbohydrates for more than five seconds.

Sinclair et. al (36) used these findings to further investigate rinse duration impact in CMR and performance benefits. The study had eleven male participants cycle for 30 minutes and rinse for five seconds or 10 seconds. The 10 second rinsing resulted in better cycling time trial performance as compared to the five second rinsing (36). The findings of this study provided insight on a potential dose-response relationship between the oral taste receptor activation and performance benefits.

**Frequency**

The amount of times that some individual rinses with carbohydrates is likely to influence intermittent sport performance. The time frame where CMR could be utilized in intermittent sport is during the brief periods of rest. A majority of studies have used a protocol that requires participants to rinse carbohydrates more than once during exercise (26,27,30,33,35,56,58). Beelen et. al (27) and Pottier et al. (33) studies involved a time trial test that had participants rinse their mouth with carbohydrates multiple times. Beelen et. al (27) investigated CMR effects after participants were fed and found no improvement in time trial performance when the participants rinsed carbohydrates every 12.5 percent of the exercise completed (8 times). Pottier et. al (33) compared carbohydrate ingestion to carbohydrate rinse and found that rinsing, but not ingestion, showed an improvement in time trial performance. However, the improvement in performance was likely related to the amount of time the carbohydrates were exposed to taste receptors in the oral cavity, rather than the number of times the participant rinsed (33). When
swallowing the carbohydrates immediately during exercise, the amount of time to influence the
taste receptor signal and brain activation may have not be long enough to impact performance.

Beaven et. al (26) and Phillips et. al (58) study protocols are both more representative of
intermittent sport performance. The protocols involved repeated sprint performance on cycles
with multiple carbohydrate rinses. Beaven et. al (26) had participants rinse for five seconds
before performing the sprints. They found that when comparing a combined caffeine-
carbohydrate rinse with carbohydrate only- mouth rinse, and a placebo mouth rinse, carbohydrate
and caffeine rinses substantially increased peak power in the first sprint (26). Because the
enhancement was seen primarily in the first sprint, where fatigue is not as likely to influence
performance, CMR may be more related to central fatigue. Phillips et. al (58) tested the
performance effects that CMR had if it was serially administered to participants prior to cycle
sprints. The serial administration resulted in total exposure time of 40 seconds prior to sprinting.
Phillips et. al (58) results fall in a similar line of Beaven et. al (26), with performance
enhancement being noticeable near the first five seconds in the beginning of the exercise
protocol.

Chong et. al (56) took frequency approach that involved carbohydrate solution ingestion
and rinsing. Twelve male participants ingested carbohydrates 20 minutes before a maximal cycle
sprint effort. Then the participants rinsed with carbohydrates 11 times in 30 second intervals five
minutes before starting the exercise. The findings suggested that a combination of carbohydrate
ingestion with CMR improves maximal sprint performance.

**Nutritional Status**

The nutritional state (low energy availability or high energy availability) of the athlete
may influence the oral cavity sensing mechanism that relates to central fatigue. The modification
of muscle function may be dependent on the pre- and post-exercise nutritional state of the body (54). Research needs to account for personalized nutritional recommendations for pre-and intra competition events for athletes. The athlete’s meals can be individualized for avoidance of GI distress and/or to optimize athletic performance. Lane et. al (31) explored the effects of CMR on high intensity cycling in either a fed or fasted state. Their results agreed with previous studies that showed a greater performance enhancement only with CMR through a fasted rather than fed nutritional state (27,29,33,88). However, consuming a carbohydrate rich meal prior to event in addition to CMR throughout the event seems to be the most beneficial for performance (31). Fares and Kayser (29) similarly investigated the impact of CMR on pre and post prandial states with a young non-athletic population. Their results were like Lane et. al (31), and they concluded that the CMR improves performance regardless of nutritional state and training status.

Glycogen Availability

Glycogen availability refers to the amount of glycogen content in the muscle available to fuel exercise. An individual may be fasted, but have high glycogen content or availability. Training approaches that involve reduced glycogen content (low glycogen availability) have been recently investigated on a molecular level to optimize skeletal muscle adaptations (41,89). Glycogen levels below 250-300 mmol·kg⁻¹ have been associated with impaired sarcoplasmic reticulum function via diminished calcium ion release rate and result in reduced peak power output (90,91). Purposely inducing this compromised muscle function with training protocols has resulted in improvements in performance in as little as three weeks (9).
Sleep-low, Train-low

Kasper et. al (42) investigated these performance improvements with participants that restricted carbohydrates. Participants were instructed to perform high intensity running to volitional exhaustion in the evening prior to the main testing trial, with no consumption of carbohydrates before going to sleep. This strategy was deemed the ‘sleep-low, train-low’ dietary exercise protocol. The following morning participants performed a 45-minute steady state run followed by a high intensity interval training (HIIT) session. Participants rinsed their mouth with carbohydrates for 10 seconds at four minute intervals during the exercise. Carbohydrate mouth rinsing improved HIIT running capacity as compared to the placebo in the carbohydrate restricted participants. These findings support other studies which found improvements in exercise performance after CMR (29,31). Furthermore, the findings allude to a hypothesis explaining that greater brain activity occurs when carbohydrate is ingested in conditions of hunger (after 12 h fast) compared to a fed state (post prandial).

Glycogen Reduced State

CMR has an effect on an individual’s performance when a participant is in a glycogen reduced state (38,92). Ali et. al (38) compared the effects of CMR had on cycling performance as compared to CHO ingestion and placebo conditions. Participants were instructed to rinse with a 15% CHO solution for about eight seconds or ingest a 7.5% CHO solution at every 12.5 percent of the exercise completed (8 times) in time trial. No performance enhancement with carbohydrate mouth rinse compared to placebo rinse conditions was seen. However, actual ingestion of carbohydrates compared to CMR resulted in an increased power output by participants. These findings suggest that CMR may influence central fatigue, and that carbohydrate ingestion is more likely to influence peripheral fatigue development. A recent study
conducted by Ataide-Silva et. al (92) found that CMR influenced exercise performance when glycogen availability was low. Furthermore, CMR provided an enhanced neural modulation with minimal metabolic alterations in participants. The low glycogen state did not compromise the skeletal muscle adaptations following training because the metabolic stress and signaling processes were preserved (92). Individuals performing high intensity exercise seem to benefit from CMR due to this metabolic condition of low glycogen status.

Summary

The effect that the direct use (training vs. competition days) of CMR has in intermittent sport performance remains to be determined. Many studies, have shown indications of improvement in performance during moderate and high-intensity exercise of at least one hour in duration, it is likely that the effect on central mechanisms of fatigue can be influenced via activation of brain regions related to reward and pleasure. Thus, adequate exposure to the oral cavity is critical for ensuring an ergogenic effect from CMR. Although nutritional status and glycogen availability has been shown to impact CMR effectiveness as an ergogenic acid, developing a strategic plan to utilize CMR during training could be extremely beneficial for performance (93). It may not be necessary to ingest amounts of CHO during exercise lasting approximately 30 to 60 minutes because CMR alone can provide performance benefit (16). CMR seems to be a more practical strategy compared to ingesting CHO solutions due to the possibility of gastrointestinal distress associated with ingestion during exercise (36). Longer CMR durations seem to elicit a greater performance benefit (36).

The ideal mouth rinsing strategy may involve a dose response relationship and incorporate other factors like concentration and frequency (36,47,87,93). Testing different CMR duration strategies on performance measures, such as peak speed, performance decrement, and...
recovery scores, may allude to ways to incorporate CMR into ergogenic nutritional strategies. However, it is still unclear what rinse duration is the most beneficial. Evidence has suggested that CMR duration of 10 seconds may be beneficial for short duration (36) intermittent sports. There has been little research conducted on a CMR that can be applied to high intensity intermittent sprints and rinsing durations longer than 10 seconds. Therefore, the purpose of this investigation is to compare the effects of two different CMR duration strategies on performance measures through a repeated sprint exercise design that incorporates a non-motorized treadmill. It is hypothesized that incrementally increasing duration of CMR (five, 10, 15 seconds) will improve performance as compared to shorter CMR (five seconds) durations.
CHAPTER III.
METHODS

Overall Design

Randomized, counterbalanced trials were conducted to test the effect on fatigue and recovery from two different durations of a carbohydrate mouth rinsing, prior to participants completing a set of anaerobic sprints (six, 35 meter sprints with 10 seconds of recovery between each sprint) in a repeated measures design (Figure 1). Two trials were performed to determine the effects that a 10% maltodextrin mouth rinse (independent variable) may have on the following measures (dependent variables): peak speed (PS), mean speed (MS), decrement in performance (% DEC), and recovery in performance (% REC), blood lactate, rating of perceived exertion (RPE), rating of perceived exertion of the entire session (S-RPE), feeling of arousal (FA) and perceived recovery status (PRS). One trial requires the participant to rinse his/her mouth with the carbohydrate solution for five seconds in duration then spit the solution out prior to each repeated sprint exercise set, while the second trial condition required the participant to rinse with the carbohydrate solution for a longer period, prior to each repeated sprint exercise set: five seconds first exercise set, 10 seconds second exercise set and 15 seconds third exercise set.

Participants

To participate within this study, male or female participants (18 years or older) must be healthy and meet health standards set by American College of Sports Medicine (ACSM). They need to be currently performing sprint training or compete in an intermittent-type sport (e.g., soccer, basketball, football) at least two days per week. Participants were required to complete a medical history questionnaire (Appendix A) with the researcher. Participants were excluded if they had any allergy to maltodextrin, had any orthopedic or musculoskeletal injury that limits sprint performance, or was considered moderate or higher risk according to ACSM guidelines.
(94). If participants experienced any discomfort or developed an illness during testing, then he or she was asked by the researcher to withdraw from the study.

![Figure 1](image)

**Figure 1.** Schematic illustration of repeated sprint protocol for each given condition excluding rinse duration. Note. Due to counterbalanced design of the study, eight participants completed the 5 second rinse condition first and five participants completed the incremental rinse condition first.

<table>
<thead>
<tr>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td># = HR</td>
</tr>
<tr>
<td>$ = RPE</td>
</tr>
<tr>
<td>$ = Blood lactate</td>
</tr>
<tr>
<td>$ = PRS</td>
</tr>
<tr>
<td>$ = FA</td>
</tr>
<tr>
<td>$ = S-RPE</td>
</tr>
</tbody>
</table>

**Participant Recruitment**

Sixteen healthy, asymptomatic men and women volunteered to participate in the study. An a priori power analysis indicated that a minimum of 8 subjects for each sex were needed to yield a power of 0.80 for detecting a moderate effect size with significance set at \( \alpha = 0.05 \).

Participants were recruited by posters and information sheets that were posted up in the Eppler Complex, Health and Human Services Building and in the Student Recreation Center (Appendix B). Announcements were also made about the investigation in Food and Nutrition (FN) and
Exercise Science (EXSC) classes (Appendix C). In addition, any individual that may hear of the study by word-of-mouth were considered if they meet the inclusion criteria.

The individuals, who expressed an interest, were to be verbally informed by the researchers about the aims, procedures and the demands of the study, as well as possible risks and discomforts that may arise during the study. After the individual completely understands the study’s procedures and has had all his/her questions satisfactorily answered, then he/she were asked to sign the informed consent form (Appendix D).

Physiological Measures

*Body Height, Mass, and Percent Body Fat*

Height (centimeters) and body mass (kilograms) of the participants were measured using a stadiometer and beam scale (Detecto Scale Company, Webb City, MO, USA). Body fat percentage estimations were performed using the 3-site method (men: chest, abdomen, and thigh; women: triceps, iliac, and thigh) by skinfold calipers (95) (Lange, Cambridge, Maryland, USA).

The descriptive data for all participants are listed in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (N=16) Mean ± SD</th>
<th>Male (N=8) Mean ± SD</th>
<th>Female (N=8) Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.0 ± 2.3</td>
<td>22.5 ± 2.7</td>
<td>21.7 ± 1.5</td>
</tr>
<tr>
<td>Height (cm.)</td>
<td>173.4 ± 8.4</td>
<td>180.0 ± 5.6</td>
<td>166.7 ± 4.5</td>
</tr>
<tr>
<td>Body mass (kg.)</td>
<td>74.3 ± 13.9</td>
<td>86.7 ± 5.9</td>
<td>62.0 ± 7.1</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>20.2 ± 4.9</td>
<td>17.2 ± 3.1</td>
<td>23.2 ± 4.6</td>
</tr>
</tbody>
</table>

*Heart Rate*

Each participant was fitted with a Polar heart rate monitor (Polar Electro, New York, USA) prior to starting standardized warm-up. The fitting involved an elastic cloth band that
hooks together with the heart rate monitor. Heart rate was provided through a telemetered system secured around the torso and communicated to a wrist watch. Participant heart rate (HR) was recorded by the researcher prior to each sprint and immediately after each sprint.

_Blood Lactate_

Blood samples to determine lactate concentration were taken from participants on both main trial days. The measurement was taken immediately following (within one minute) each repeated sprint exercise set by means of a finger stick and capillary puncture, and the blood analyzed with an enzymatic portable blood lactate analyzer (Lactate Plus; Nova Biomedical Corp., Waltham, WA, USA). The lactate analyzer was calibrated in compliance with the manufacturer’s instructions and has been validated in other studies (96). Blood lactate measures were used to assess exercise intensity.

**Perceptual Measures**

_Arousal Level_

The Felt Arousal Scale (FAS) (97) in Appendix E was used to measure participants’ level of arousal/activation. Arousal/activation was assessed after each sprint on the main trial testing days. The scale ranges from one indicating low arousal/activation meaning feeling bored, relaxed, and calm to six which indicates high arousal/activation meaning feeling angry or excited.

_Perceived Exertion_

The Ratings of Perceived Exertion OMNI Scale (RPE) (98) in Appendix F was used to measure participants’ perceptual feelings of the level of effort given during the repeated sprint exercise on a scale from zero to 10. The anchor set at zero indicates effort feelings of extremely
easy meaning the exercise felt effortless. The anchor set at 10 indicates feelings of extremely hard meaning the exercise felt like maximal effort was used.

The Session Rating of Perceived Exertion Scale (S-RPE) (99) in Appendix G was used to measures participants’ perceptual feelings of effort given in relation to the entire sprint exercise session. The S-RPE scale is anchored on a scale from zero to 10. The anchor set a zero is the exertion felt at rest. The anchor set at 10 is the exertion felt at maximal effort.

Perceived Recovery

The Perceived Recovery Scale (PRS) (100) in Appendix H was used to measure participants’ feelings of recovery relative to subsequent exercise sprint performance. The scale is like the Adult Omni perceived exertion scale in that it sets feelings on a ten-point scale. Anchors of the PRS are set at zero indicating feelings of being very poorly recovered/extremely tired) and ten indicating very well recovered/ highly energetic.

Rate of Fatigue

A decrement score was calculated to analyze the rate of fatigue for each repeated sprint (101). The decrement score will be calculated by dividing the difference between the average power of the sprint and peak power of the sprint and multiplying it by 100. A higher decrement score means a higher rate of fatigue. A lower decrement score means a lower rate of fatigue.

Power Recovery

A recovery score was calculated to determine the amount of power recovered between each repeated sprint exercise set (101). Recovery scores are determined by dividing the difference of the mean speed of the entire repeated sprint set and subsequent sprint set by the
average sprint time of the sprint exercise set. This remaining value then is subtracted from one and then multiplied by 100. A higher recovery score means a higher amount of relative power recovered. A lower recovery score means a lower amount of relative power recovered.

Diet Control

Before testing, participants were asked to avoid caffeine for four hours, refrain from intense physical activity for 24 hours prior to both testing days. Participants received an educational with a handout about an ideal competition meal and then asked to record their dietary intake 24 hours prior to the first testing day (Appendix I). They were asked to replicate the same diet 24 hours to the next testing day (Appendix J). During the recovery period, each participant was permitted to drink water ad libitum within the first 2 minutes of the entire 7-minute period.

Carbohydrate Rinse Solution

The participants were required to swish a 25 mL solution of 10% maltodextrin (10 g of maltodextrin and 100mL of distilled water) within their mouths for a designated time of five, 10, or 15 seconds (31,33,55,57). The mouth rinse was self-administered, and participants were asked to swish the rinse vigorously in their mouth for the required duration. Then they were asked to spit the solution into a styrofoam cup that has been pre-weighed using an electronic scale (Fristaden & Company LLC, Chicago, Illinois, USA). Styrofoam cups were reweighed to assess the amount of solution spit back into the cup to determine unintentional swallowing of the solution by the participant.
Testing Protocol

Familiarization Trial

Prior to both testing days, a familiarization trial was conducted in the laboratory, first the participant’s height (cm.) and body mass (kg), body fat percentage, and age (yr.) were recorded. Participants began a standardized warm-up that was adopted from procedures developed by Vetter (102) and completed it prior to beginning the repeated sprint exercise test (Table 2). The warm-up will consist of a four-minute walk at 3.7 miles per hour on motorized treadmill, a two-minute run at 7.5 miles per hour on the motorized treadmill and three sets of 10 repetitions of active stretching. Once the warm-up is completed, the participant performed one repeated sprint exercise set on a non-motorized treadmill, to familiarize with the sprint exercise sets. Raw treadmill belt speed data (peak speed [m·s] and mean speed [m·s]) from the non-motorized treadmill was recorded by a transducer in the non-motorized treadmill platform and monitored in “real time” on a personal computer containing the manufacturer’s computer software (World Wide Software Solutions Firmware version 1.32). Then participants were instructed how to complete the dietary record sheet prior to the main trial days.

Table 2. Standardized warm-up protocol

<table>
<thead>
<tr>
<th>Dynamic warm-up exercise</th>
<th>Repetitions</th>
<th>Cadence (repetitions per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toe raises</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>High knee marches</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Butt kicks</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

Main Trial One Testing

After the familiarization trial, the participant scheduled two main trial testing days for a repeated sprint exercise testing, then the researcher reviewed the procedures for the repeated sprint exercise protocol with the participant. After a warm-up session, the participants had their HR recorded. The repeated sprint exercise protocol includes three repeated sprint exercise sets with a seven-minute passive rest and a five second carbohydrate rinse self-administered 20 seconds prior to each set (condition one). The recovery period of seven minutes was chosen to allow maximal phosphocreatine repletion (103). One set of repeated sprints will consist of six 35-meter all-out sprints separated by 10 seconds (104). During each sprint, the researcher counted down from 10 seconds, and the participant was expected to reach maximal sprint effort by zero seconds. Immediately after the completion of the 35-meter sprint, the participant was given a verbal cue to straddle the treadmill belt for their 10 second recovery period. Verbal encouragement was provided to all the participants throughout the series of repeated sprint exercises. After each sprint, the participant was asked how hard he or she worked on a scale of 1-10 and had his or her heart rate recorded. After each repeated sprint exercise set, the participant was instructed to sit in a chair and rest for seven minutes. This was the period where blood lactate was assessed. With twenty seconds remaining in the recovery period, the participant gave his or her PRS, and then rinsed with the carbohydrate solution and provided an FA. Consumption of water was permitted during this specific recovery period for only two of the seven minutes. This process was repeated for a total of three exercise and recovery bouts. After completing all the repeated sprint exercise sets, the participant was asked to give a S-RPE after fifteen minutes has gone by since completion of the entire repeated sprint exercise protocol.
Main Trial Two Testing

The second condition for carbohydrate rinsing was tested a minimum of 48 hours after completion of the first testing condition and maximum of 72 hours for carbohydrate rinsing. The only difference between the two testing conditions was the rinsing duration between repeated sprint exercise sets. The second day of testing (condition two) consisted of incremental increases in rinsing time prior to each repeated sprint exercise set. The participant rinsed for five seconds prior to the first set, 10-seconds prior to the second set, and 15-seconds prior to the third set.

Statistical Analysis

A 2 (condition) x 3 (RAST) x 2 (Sex) repeated measures ANOVA was performed to determine main effects for mean speed, peak speed, decrement score, recovery score, felt arousal, and RPE. Paired t-tests with a Bonferroni correction applied to the alpha level were used to determine any significant differences between condition and/or RSE if a main effect was observed. Additionally, session RPE was analyzed using a paired t-Test. Effect sizes (\(\eta^2\)) and statistical power (\(N - B\)) were also calculated for main effects. Cohen’s d effect sizes for the session rating of perceived exertion measure was calculated (105) (i.e., small effect size \(d = 0.20\), medium effect size \(d = 0.50\), large effect size \(d = 0.80\)). All data is presented as a mean ± standard deviation. Statistical significance was determined at \(\alpha \leq 0.05\). All data was analyzed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA).
CHAPTER IV.
RESULTS
Overview

All the descriptive data for all participants are listed in Table 1. The study was randomized and consisted of counterbalanced sprint trials that were conducted to test the effect on fatigue and recovery from two different durations of a carbohydrate mouth rinsing (CMR). Participants completed a set of anaerobic sprints (six, 35 meter sprints with 10 seconds of recovery between each sprint) in a repeated measures design (Figure 1). One trial requires the participant to rinse his/her mouth with the carbohydrate solution for five seconds in duration, then spit the solution out prior to each repeated sprint exercise set (condition 1), while the second trial condition required the participant to rinse with the carbohydrate solution for a longer period prior to each repeated sprint exercise set: five seconds first exercise set, 10 seconds second exercise set and 15 seconds third exercise set (condition 2). The standardized warm-up used in the study was adopted from procedures developed by Vetter (102) and was completed by participants prior to beginning the repeated sprint exercise test (RSE) (Table 2 Ch. 3, pp. 31).

Speed
Average Speed

The average speed achieved in RSE sets for both conditions is modeled in figure 2. A repeated measures ANOVA revealed no main effect of condition on average speed (F1, 13 = .712, p = 0.414, \(\eta^2 = 0.052\); N-\(\beta = 0.123\)). There was a significant main effect of RSE set on average speed (F2, 26 = 20.234, p < 0.001, \(\eta^2 = 0.609\); N-\(\beta = .997\)). A paired t-test revealed no significant difference between average speed when comparing condition one and condition two in each RSE set (RSE\(_1\) p = .610, RSE\(_2\) p = .266, RSE\(_3\) p = .171). Additionally, no significant interaction effect of condition x RSE set on average speed (p = 0.283) was found.
Figure 2. Average speed achieved during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16).

Peak Speed

The peak speed achieved in RSE sets for both conditions is shown in Figure 3. A repeated measures ANOVA revealed no main effect of condition ($F_{1, 13} = .107, p = 0.179, \eta^2 = 0.134; N-\beta = 0.261$). There was a significant main effect of RSE set on peak speed ($F_{1.401, 18.216} = 20.845, p < 0.01, \eta^2 = 0.616; N-\beta = .998$). Additionally, no significant interaction effect of condition x RSE set on peak speed ($p = 0.329$) was found.

Figure 3. Peak speed achieved during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16).
**Sex**

Average speed achieved for both males and females in each condition is shown in figure 4. A repeated measures ANOVA revealed no main effect of condition ($F_{1, 13} = .142, p = 0.713, \eta^2_p = 0.011; N-\beta = 0.064$) or RSE set on average speed ($F_{1.311, 17.043} = .053, p = 0.881, \eta^2_p = 0.004; N-\beta = .056$) between sex. There was no significant interaction effect of condition x RSE set between sexes ($p = 0.877$).

![Figure 4](image)

Figure 4. Average speed achieved during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants.

Peak speed achieved for both males and females in each condition is shown in figure 5. A repeated measures ANOVA revealed no main effect of condition ($F_{1, 13} = 1.147, p = 0.304, \eta^2_p = 0.081; N-\beta = 0.168$) or RSE set on peak speed ($F_{1.401, 18.216} = .101, p = 0.835, \eta^2_p = 0.008; N-\beta = .064$) between sex. There was no significant interaction effect of condition x RSE set between sexes ($p = 0.993$).
Figure 5. Peak speed achieved during each RSE under set condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants.

Perceptual Measures

*Rating of Perceived Exertion (RPE)*

The rating of perceived exertion in all RSE sets for both conditions is shown in figure 6. A repeated measures ANOVA revealed no main effect of condition ($F_1, 13 = 1.965, p = 0.184, \eta^2_p = 0.131; N-\beta = .255$) on rating of perceived exertion. There was a significant main effect of RSE set ($F_2, 26 = 16.807, p < .001, \eta^2_p = 0.564; N-\beta = 0.999$) on rating of perceived exertion. Additionally, no significant interaction effect of condition x RSE set on rating of perceived exertion ($p = 0.138$) was found.
Figure 6. Mean rating of perceived exertion reported during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16).

Perceived Recovery Status (PRS)

The perceived recovery status in all RSE sets for both conditions is modeled in figure 7. A repeated measures ANOVA revealed no main effect of condition (F1, 13 = .361 p = 0.558, \( \eta^2 = 0.027 \); N-\( \beta = 0.086 \)) on perceived recovery status. There was a significant main effect of RSE set (F2, 26 = 18.324, p < .001, \( \eta^2 = 0.585 \); N-\( \beta = 0.996 \)) on perceived recovery status. Additionally, no significant interaction effect of condition x RSE set on perceived recovery status (p = 0.213) was found.
Figure 7. Mean perceived recovery reported after each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16).

PRS Sex Differences

Male and female perceived recovery status in all RSE sets for both conditions are shown in figure 8. A repeated measures ANOVA revealed no main effect of condition (F1, 13 = .084, p = 0.777, ηp² = 0.006; N-β = 0.058) or RSE set on perceived recovery status (F1.444, 18.773 = 0.492, p = 0.559, ηp² = 0.036; N-β = .110) between sexes. There was no significant interaction effect of condition x RSE set between sex (p = 0.529).

Figure 8. Mean perceived recovery reported after each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants.

RPE Sex Differences

Male and female rating of perceived exertion in all RSE sets for both conditions is shown in figure 9. A repeated measures ANOVA revealed no main effect of condition (F1, 13 = 1.584, p = 0.230, ηp² = 0.109; N-β = 0.215) or RSE set on rating of perceived exertion (F2, 26 = .050, p
= 0.952, $\eta^2 = 0.004; \text{N-}\beta = .057)$ between sexes. There was no significant interaction effect of condition x RSE set between sex ($p = 0.227$).

![Figure 9](image_url)

Figure 9. Mean rating of perceived exertion reported during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants.

**Session Rating of Perceived Exertion (S-RPE)**

Figure 10 displays the session RPE reported by male and female participants in all RSE sets for both conditions. A paired t-test revealed that session RPE did not significantly differ between condition 1 and condition 2. ($p = .288; d = 0.340$) or between males ($p = 0.104; d = 0.468$) and females ($p = 0.715; d = 0.208$).
Figure 10. Session rating of perceived exertion reported after completion of testing between females (N=8) and males (N=8) under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16).

Physical Measures

*Blood Lactate*

Blood lactate concentration in all RSE sets for both conditions is shown in figure 11. A repeated measures ANOVA revealed no main effect of condition (F1, 13 = 1.243 p = .285, \(\eta^2 = 0.087\); N-\(\beta = .179\)) on blood lactate. There was a significant main effect of RSE set (F2, 26 = 39.568, p < .001, \(\eta^2 = 0.753\); N-\(\beta = 1.000\)) on blood lactate. Additionally, no significant interaction effect of condition x RSE set on blood lactate (p = 0.058) was found.
Figure 11. Blood lactate levels immediately following each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16).

Blood Lactate Sex Differences

Both male and female blood lactate concentration for all RSE sets for both conditions is shown in figure 12. A repeated measures ANOVA revealed no main effect of condition (F1, 13 = .069, p = 0.797, ηp² = 0.005; N-β = 0.057) or RSE set on blood lactate (F2, 26 = 1.331, p = 0.282, ηp² = 0.093; N-β = .261) between sexes. There was no significant interaction effect of condition x RSE set between sex (p = 0.059).

Figure 12. Blood lactate levels immediately following each RSE set during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants.
Felt Arousal (FAS)

The rating of perceived activation in all RSE sets for both condition is shown in figure 13. A repeated measures ANOVA revealed no main effect of condition ($F_{1, 13} = 0.098, p = 0.759, \eta^2 = 0.007; N-\beta = 0.060$) and RSE set ($F_{1.71, 15.227} = 0.977, p = 0.353, \eta^2 = 0.070; N-\beta = 0.160$) on rating of perceived activation. Additionally, no significant interaction effect of condition x RSE set on rating of perceived activation ($p = 0.269$) was found.

![Figure 13. Mean rating of perceived activation reported during each RSE set under condition 1 and condition 2 (N = 16). Condition 1 is the five second rinse strategy and Condition 2 is the incremental rinse strategy (five, 10 and 15 seconds).](image)

Felt Arousal Sex Differences

Male and female rating of perceived activation in all RSE sets for both conditions is shown figure 14. A repeated measures ANOVA revealed no main effect of condition ($F_{1, 13} = 0.639, p = 0.438, \eta^2 = 0.047; N-\beta = 0.115$) or RSE set on rating of perceived activation ($F_{1.171, 15.227} = 2.558, p = 0.127, \eta^2 = 0.164; N-\beta = 0.345$) between sex. There was no significant interaction effect of condition x RSE set between sexes ($p = 0.485$).
Figure 14. Mean rating of perceived activation reported during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants.

Fatigue and Recovery Rates

*Decrement Score*

The decrement of speed in each RSE sets is modeled for both conditions in figure 15. A repeated measures ANOVA revealed no main effect of condition (F1, 13 = 1.294, p = 0.276, $\eta^2_p = 0.091$; N-\(\beta\) = .184) and RSE set (F2, 26 = .980, p = 0.389, $\eta^2_p = 0.070$; N-\(\beta\) = 0.202) on decrement score. Additionally, no significant interaction effect of condition x RSE set on decrement score (p = 0.795) was found.
Figure 15. The speed decrement that occurred during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16).

Decrement Score Sex Differences

The decrement of speed for both males and females in all RSE sets for both conditions is modeled in figure 16. A repeated measures ANOVA revealed no main effect of condition ($F_{1, 13} = .951$, $p = 0.347$, $\eta^2_p = 0.068$; $N-\beta = 0.148$) or RSE set on decrement score ($F_{2, 26} = .421$, $p = 0.661$, $\eta^2_p = 0.031$; $N-\beta = .111$) between sexes. There was no significant interaction effect of condition x RSE set between sex ($p = 0.817$).
Figure 16. The speed decrement that occurred during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants.

Recovery Score

The recovery of speed in all RSE sets for both conditions is shown in figure 17. A repeated measures ANOVA revealed no main effect of condition (F1, 13 = 1.349, p = 0.266, \( \eta^2 = 0.094 \); N-\( \beta \) = .190) and RSE set (F2, 26 = .943, p = 0.402, \( \eta^2 = 0.068 \); N-\( \beta \) = 0.195) on recovery score. Additionally, no significant interaction effect of condition x RSE set on recovery score (p = 0.847) was found.
Figure 17. The recovery of speed that occurred during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) (N=16).

**Recovery Score Sex Differences**

The recovery of speed in all RSE sets for both males and females for each condition is shown in figure 18. A repeated measures ANOVA revealed no main effect of condition (F1, 13 = 0.977, p = 0.341, $\eta^2_p = 0.070$; N-\(\beta\) = 0.150) or RSE set on recovery score (F2, 26 = 0.457, p = 0.638, $\eta^2_p = 0.034$; N-\(\beta\) = 0.116) between sexes. There was no significant interaction effect of condition x RSE set between sex (p = 0.852).

Figure 18. The recovery of speed that occurred during each RSE set under condition 1 (repeated five second rinse strategy) and condition 2 (incremental five, 10 and 15 second rinse strategy) with female (N=8) and male (N=8) participants.
CHAPTER V.
DISCUSSION
Overview

The purpose of this study was to determine if self-administration of different carbohydrate mouth rinsing (CMR) durations influence repeated sprint performance. While most of the studies have investigated the impact of CMR by participants cycling, this is the first study aimed to examine the influence of a CMR duration of greater than 10 seconds in participants running repeated sprints. Additionally, the investigation allows for a comparison between male and female sprinting performance in response to CMR. The most important finding from this study reveals that administration of CMR with increasing duration did not significantly attenuate average or peak sprint performance (Figure 2 and 3). Furthermore, the influence of CMR on sex did not show a statistical difference between male and female sprinters (Figure 4 and 5).

However, during latter portions of the repeated sprint protocol (repeated sprint sets two and three), average speed of participants showed a trend towards a difference between rinse conditions in repeated sprint set 2 (RSE$_{2}$) and repeated sprint set 3 (RSE$_{3}$). The difference was most noticeable in RSE$_{2}$ and to a lesser extent RSE$_{3}$. There were no statistical significant differences in speed or in either immediate or global perceptual strain (e.g., RPE, PRS, SRPE), or metabolic strain (e.g., blood lactate) throughout the entire RSE sets.

The trend seen in peak speed and lack of difference seen in average speed, may suggest that the incremental rinse strategy to have a reduction in power as an ergogenic aid to attenuate fatigue in repeated sprints. The repeated sprint protocol may have created a point in sprinting where fatigue development overpowers CMR as an ergogenic aid (106,107). The design of a
repeated sprint protocol is important to consider, as some studies have suggested that protocols of a lower intensity are less likely to show an ergogenic effect from CMR (108,109). Thus, this study’s sprint design was predominately focused on a high demand of maximal effort at a high intensity. Furthermore, this particular design may have elicited a strong metabolic strain that influences the feedback from the periphery, resulting in an “overpowering” signal on the central mechanism that CMR has been linked with in exercise performance (110,111). Regardless of the CMR durations, the increasing RPE values in this study suggest a strong increase in perceptual strain and reduced recovery, both which indicate striking peripheral responses to exercise (112,113).

Fatigue Development from Repeated Sprints

Although the repeated sprint design influenced peak and average speed in sprint performance across each RSE set, the statistical analysis revealed no perceptual or metabolic differences of fatigue. It is important to note that most individuals accustomed to a sprint type of training are able to reproduce sprint performance with similar perceptual and metabolic measures with suboptimal to optimal recovery (114). Thus, a consistent increase in RPE and decrease in PRS would reflect the consistency of performance between a randomized, counter-balanced sprint design (Figure 5). Indeed, the participants sprinting in this study showed increases in RPE and decreases in PRS over the RSE sets in both conditions (Figure 6 and 7). Furthermore, blood lactate was consistent between RSE sets, indicating participant sprint intensity was maximal for both conditions and sexes (Figure 11 and 12). The latter stages of repeated sprints are where an individual under normal conditions may experience a loss in optimal performance due to negative consequences of high intensity work (i.e. pH disruption, metabolic by-product accumulation) (107). Additionally, these latter stages are considered difficult glycolytic
conditions in which the CMR duration could be most influential on performance (112). This sprint design of the study results in inevitable glycolytic conditions, reinforcing the prescription of increasing CMR duration by five seconds after completion of every sprint set. Although not significant, an attenuation of peak speed is seen throughout RSE$_2$ and RSE$_3$, suggesting that CMR duration may still be an important variable to consider when employing CMR strategies in repeated sprint work.

Performance Outcomes Between Sex

A unique approach of this study not only incorporates running the repeated sprints, but an additional assessment of changes in perception (i.e. perceived recovery status, perceived rating of exertion, and perceived activation) and determination of differences between sexes. Only a few studies have incorporated females as participants when evaluating the effect of CMR on performance (51–53). The running of repeated sprints strengthens the ecological validity of this study when considering the number of sports involve running and are intermittent in nature (115). It is critical to consider sex differences given the emphasis from the recent literature to evaluate males and females separately for an assessment of repeated sprint ability (116–118).

Although this study showed that CMR durations do not influence sex in terms of sprint performance, there was consistency with male sprinters displaying a greater peak and average speed throughout each repeated sprint set as compared to female sprinters. Males may have different neuromuscular recruitment patterns than females during exercise that is exhaustive enough to elicit strong levels of neuromuscular fatigue (118). Thus, it seems plausible that there
may have been increased motor unit recruitment strategy that could have facilitated increases in peak and average speed in males as compared to females. It may be then, as previous literature suggests, that the significantly lower speed was generated in the five second rinse condition as result of down-regulation of motor unit recruitment rather than a decrease effort (119).

Additionally, past research has suggested that females demonstrate an improved recovery during self-paced high intensity exercise as compared to males (116). This is interesting because CMR is thought to provide an ergogenic effect through a central mechanism that allows individuals to work harder at the same subjective perception of exertion (120). The unconscious increase in the self-chosen pace and improvement in performance may be related to the suppression of afferent signals of muscle fatigue or a motivation effect. Further research is needed to examine if self-administration of CMR facilitates motor unit recruitment (e.g., recruitment strategies and/or alterations in muscular recruitment) and motivation between males and females.

CMR Duration Effect on PRS and RPE

The Perceived Recovery Status Scale, was used to identify any perceived changes in recovery. The tool’s original purpose was designed to monitor recovery on a day to day basis to ensure that overtraining did not occur or to detect under-recovery (121). However, a modified version of this scale was used to assess changes in perceived recovery status relative to expected performance between exercise bouts. Both males and females from this repeated sprint design showed no difference in perceived recovery status (Figure 10). Which is further supported by the lack of significant differences found between recovery (REC) scores, RPE, nor session rating of perceived exertion (S-RPE) between conditions. It appears the administration of different CMR
durations does not cause a disassociation between subjective recovery and physiological recovery. This lack of sex difference in perception of recovery status is something that is difficult to explain considering the main effect seen with rating of perceived exertion throughout the sprint sessions (Figure 9). Regardless, the design and focus of this study suggests that an individual sprinter will still be able to determine if he or she is adequately recovered to perform optimally, rather than continue training unrecovered and have suboptimal performance. Preventing athletes to reach an over-trained state will limit decreases in performance (122).

The RPE rise throughout the repeated sprint bouts shown in this study is expected (Figure 6), as several studies have shown that RPE increases as the total amount of work increases (113,123–125). The lack of a significant difference in RPE between conditions suggests that increasing the rinse duration may not help undue the fatigue developed during the latter stages of sprinting, and may not be the best method to employ to show improved repeated sprint performance. Interestingly, S-RPE also remained relatively similar between both conditions (Figure 10), suggesting that the global difficulty was the same between both conditions. This is also expected when considering the minimal changes seen in RPE between conditions. Thus, the ergogenic effect of CMR durations is limited to the actual session. The participants in the incremental rinse condition did not feel that the session was any more difficult than when sprinting in the five second rinse condition. There were no differences, either statistically or practically between males and females from both a perceptual strain and overall global difficulty standpoints. It seems perception of effort during high-intensity bouts are stable within sex regardless of CMR rinse duration.

CMR Impact on Fatigue
It is important to remember that muscle damage impairs performance, increases RPE, and decreases the amount of work able to be completed (126). The administration of incremental rinse could have modulated the sensation of pain due to the inhibition of nociceptive signals at the level of the spinal cord (127). This action would trigger an up-regulation in sprint performance or reduce the decline in performance as seen in this study, though not statistically significant. The sprint performance could be based upon a pre-exercise mental pattern designed to up-regulate or down-regulate performance contingent upon the comparison of a person’s expected exertion and recovery to their actual exertion and recovery during the sprints (128). CMR may have influenced the nociceptive signal to the CNS, perhaps due to the incremental rinsing strategy, further allowing a regulation of performance via increased motor unit recruitment to muscles as suggested by other CMR studies (108,129). However, it seems the increasing rinse strategy alone may not be enough to generate statistically significant differences in sprint speed.

Felt Arousal and Perception

Participant perceived activation (felt arousal) was assessed in both conditions to help gain a better understanding towards mouth rinsing duration and subjective experiences during high intensity exercise. In a study conducted by Backhouse et al. (130), participants were more activated during the final 30 minutes of a prolonged high intensity exercise post carbohydrate ingestion. However, perceptual responses vary within the literature where Beelen et a. (131) found CMR had no ergogenic effect, and Rollo et al. (132) reported that CMR significantly increased pleasurable feelings in comparison with a placebo solution. The current study was unable to statistically improve participant perceived activation and falls in agreement with Dorling and Earnest (113) that involved a similar high intensity sprinting protocol. Although,
there was a slight attenuation in peak and average speed, perceived activation remained relatively stable throughout repeated sprint sets, (Figure 13) and showed no influence between sex (Figure 14). This may attest to the required maximal performance in the sprint design and its ability to override any motivation to perform well may negate any small changes in the feelings of activation induced by the presence of CHO in the oral cavity (110). Thus, incremental rinse duration did not optimize CMR as a method to generate a pleasurable overriding response in maximal effort repeated sprint ability.

Overall, perceived activation may have a limited role in helping to detect an up-regulation in performance to allow for greater maintenance of peak and mean speed in the incremental rinse condition, despite similar RPEs and PRS reported across both conditions. However, it is important to consider Ali et al.’ (123) findings involving ingestion and rinsing and the resulted values of high-activation regardless of carbohydrate administration. Thus, the use of felt arousal scale alone may not be sensitive enough to detect and help explain central adaptations, and the differences seen likely to related to differences in study design.

Decrement and Recovery of Speed

Relative measures (DEC and REC scores) of fatigue rate and recovery rate were also used in this study. The decrements in performance were not significantly different between CMR duration conditions, suggesting that the decay in speed output within repeated sprint set was unaffected by the administration of increasing mouth rinsing durations (Figure 15 and 16). Additionally, the ability to recover speed was not significantly different between conditions, like what was observed with DEC scores (Figure 17 and 18). However, these findings are worthy of closer examination. Although conditions were not significantly different in terms of relative
speed recovered, the incremental rinse condition seemed to produce higher peak speed in RSE$_2$ and RSE$_3$.

The incremental rinse may improve recovery by facilitating a modification of a pre-exercise mental pattern to allow for an increased speed while the modulation of pain maintains RPE despite the increased work rate. Furthermore, males seem could have been more sensitive to the mouth rinse durations than females, suggesting a difference in modification of pre-exercise mental patterns via CMR (Figure 16 and 17) between sex. Women have been shown to generally report the same average RPE and S-RPE values (116,133). The results in this study fall in line with women reporting the same average RPE and S-RPE (Figure 11). However, ergogenic aids that may influence performance via suppression of afferent signaling from muscle fatigue may be different between males and females, suggesting that anterior cingulate cortex and right caudate (forms part of the striatum) activation may be different. Thus, males and females may have different interpretations of reward and control from CMR of varying durations, rather than actual caloric content of the carbohydrate mouth rinse. Further research to investigate differences between males and females and carbohydrate mouth rinsing is needed.

Limitations

In addition to noting the novel findings of this study, it is important to state the limitations to sufficiently apply them. The most obvious limitations of this study design were the lack of blinding and use of a placebo. Some CMR studies have utilized a placebo in design to help delineate the effect of CMR as potential performance enhancer (112,134). The choice to not include a placebo in this study was based on the context of a written review provided by Cox and
Stellingwerff (112). The authors explain that 82% of the studies in their review showed statistically significant performance benefits from carbohydrate supplementation while only 18% show no change compared with placebo (112). Furthermore, a study was conducted to show what would happen if the mouth and gastrointestinal (GI) tract were both bypassed by carbohydrates (135). This study found that infusion of carbohydrates straight into the bloodstream resulted in unaltered performance as compared with no CHO supplementation. Thus, the intention of this study was to focus on optimizing CMR as an ergogenic aid rather than solely determining if it has ergogenic effect on performance. This focus is further supported by a recent study quantifying the effect of CMR on exercise performance as small and trivial (136). As for the limited blinding in the study, its rinse duration component makes it difficult to maintain consistent complete blindness. However, it would be worthy to note that participants provided feedback suggesting that it was difficult to notice and determine which condition was experienced during the testing session after completion of the entire testing regimen.

**Application**

Another potential limitation in the study may have been related to diet consistency within participant sessions. Although the dietary records were reviewed and checked for consistency, the information is self-reported which is susceptible to participant bias. An inconsistency in diet may influence the sensitivity to the CMR strategy because of its relatedness to differences in muscle and liver glycogen content. However, a study conducted by Lane et al (137) showed performance improvements regardless of nutritional state (glycogen storage) and suggested that the ergogenic effect is maximized when subjects consumed carbohydrates and rinsed their mouths with carbohydrates as opposed to participants solely rinsing their mouths with carbohydrates. Competing and training in a fasted state is not an ideal strategy for most athletes.
This study involved an educational session that encouraged participants to consume a carbohydrate meal relative to the intensity of the exercise to maximize sprint performance, further contributing to the ecological validity of its design. Moreover, Thays de Ataide e Silva et al. (134) made a valid point in a systematic review that addresses the impact of fasting has on performance. The authors explained from another study that other factors like music can mask the influence of a fasted state while still showing performance improvements (139). Ultimately, they found that the beneficial effect of CMR on performance is more related to other factors and less related to duration of fasting. Additionally, the sample size in the current study was small which may limit the application of findings.

Conclusion

Finally, to further improve this study an incorporation of electromyography (EMG) and electroencephalography (EEG) could provide strong evidence for decreased fatigue between the different rinse conditions, as research has shown that muscular fatigue is partly due to feedback from a central governor and that carbohydrate containing solutions activate positive afferent signals from a central level (108). Future studies investigating the carbohydrate mouth rinsing durations and its impact on motor recruitment patterns in repeated sprints are needed. Additionally, researchers should consider gathering more information to further understand the perceptual responses that relate the central and peripheral integration of fatigue with carbohydrate supplementation in intermittent sports.

In conclusion, findings from the current study does not support the hypothesis about an administration of a CMR with increasing durations improving repeated sprint performance.
Specifically, despite similar perceptual and metabolic response through both conditions, there may be sex differences in response to CMR when considering small amount of evidence explaining performance differences between males and females. More research involving female participants would help strengthen the utility of CMR as an ergogenic aid. Future work investigating the effect of CMR durations at different exercise intensities with EMG data over longer time periods could significantly contribute to body of literature on CHO supplementation.
REFERENCES


Appendix A. MEDICAL HISTORY QUESTIONNAIRE

EXERCISE PHYSIOLOGY LABORATORY
124 EPPLER SOUTH, SCHOOL OF HMSLS
BOWLING GREEN STATE UNIVERSITY
MEDICAL HISTORY QUESTIONNAIRE

All information given is confidential. It will enable us to better understand you and your health and fitness habits. In addition, we will use this information to classify your health status according to the American College of Sport Medicine (ACSM) recommendations for risk stratification (ACSM, 2010). Please let us know when you have changed your medication (dose & type), diet, exercise or sleeping habits within the past 24 or 48 hours. It is very important for you to provide us with this information.

NAME______________________________________________  AGE___________________
DATE______________________
OCCUPATION_________________________________________________________________

1. *FAMILY HISTORY

Check each as it applies to a blood relative:

Heart Attack yes______ no______
unsure______
If yes, age at onset ___ yrs; relation to you ________________

Sudden Death yes______ no______
unsure______
If yes, age at onset ___ yrs; relation to you ________________

Coronary Revascularization
If yes, age at onset ___ yrs; relation to you ________________
Father’s Age_____ Deceased______ Age at death______
(*Before 55 yr. in father or first-degree male relative)

Tuberculosis yes______ no______
unsure______

Stroke yes______ no______ unsure______
Asthma yes______ no______ unsure______

High Blood Pressure yes______ no______
unsure______
Circulatory Disorder yes______ no______
unsure______

Heart Disease yes______ no______
unsure______
Mother’s Age______ Deceased______
Age at death______
(*Before 65 yr. in mother or first-degree female relative)
2. PERSONAL HISTORY

* Age (men ≥ 45 yr.; women ≥ 55 yr.)
  yes ______ no ______

* Current Cigarette Smoking
  yes ______ no ______ unsure ______

* Sedentary Lifestyle
  yes ______ no ______ unsure ______

Persons not participating in at least 30 min of moderate intensity physical activity on at least 3 days/wk. for at least 3 months.

* Obesity – BMI > 30 kg·m-2
  yes ______ no ______ unsure ______

If yes, give value: ____ kg·m-2

Waist circum. > 40” men; 35” women:
  yes ______ no ______

* High Blood Pressure

Systolic Blood Pressure > 140 mmHg or diastolic > 90 mmHg
  yes ______ no ______ unsure ______

If yes, give value: ____ / mmHg.

* Dyslipidemia

Total Serum Cholesterol > 200 mg·dl-1;
  value: mg·dl-1
  yes ______ no ______ unsure ______

LDL-C ≥ 130 mg·dl-1; value: mg·dl-1
HDL-C ≤ 40 mg·dl-1; value: mg·dl-1

On lipid lowering medication:
  yes ______ no ______ unsure ______

* Prediabetes
  yes ______ no ______ unsure ______

If yes, age of onset: ______ years

Impaired fasting glucose ≥ 100 mg·dl-1;
  value: mg·dl-1

Impaired glucose tolerance test:
  yes ______ no ______

(Note: values confirmed by measures on two separate occasions)

* Negative Risk Factor:

HDL ≥ 60 mg·dl-1; value: ____ mg·dl-1
  yes ______ no ______ unsure ______

Have you ever had?:

Diabetes yes ______ no ______ unsure ______

Tuberculosis yes ______ no ______ unsure ______

Heart Attack yes ______ no ______ unsure ______

Angina yes ______ no ______ unsure ______

EKG Abnormalities yes ______ no ______ unsure ______

Asthma yes ______ no ______ unsure ______

Emphysema yes ______ no ______ unsure ______

Surgery yes ______ no ______ unsure ______

Stroke yes ______ no ______ unsure ______

Severe Illness yes ______ no ______ unsure ______

Hospitalized yes ______ no ______ unsure ______

Black Outs yes ______ no ______ unsure ______

Gout yes ______ no ______ unsure ______
Nervousness yes______ no______ unsure______
Joint Problems yes______ no______ unsure______
Allergy yes______ no______ unsure______
Convulsions yes______ no______ unsure______
Paralysis yes______ no______ unsure______
Headaches yes______ no______ unsure______
Depression yes______ no______ unsure______
Chest Pain yes______ no______ unsure______
Arm Pain yes______ no______ unsure______
Shortness of Breath yes______ no______ unsure______
Indigestion yes______ no______ unsure______
Ulcers yes______ no______ unsure______
Overweight yes______ no______ unsure______
Hernia yes______ no______ unsure______
Back Pain yes______ no______ unsure______
Leg Cramps yes______ no______ unsure______
Low Blood Pressure yes______ no______ unsure______
Insomnia yes______ no______ unsure______

For Researcher Use Only:

Sum of positive and negative *CVD risk factors* (according to Table 2-3 ACSM (2009))

NOTE: All risk factors are explained verbally to each person completing the questionnaire.

Classification according to ACSM (2009) (circle one): Low risk; Moderate risk; High risk

3. MEDICAL HISTORY

Allergic to Maltodextrin? _______ Yes _______ No
Name of your physician
________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________
What did the physical examination include?

Have you ever had an exercise EKG? Yes_______ No________

Are you presently taking any medications? Yes_______ No________

If yes, list medications (Including over-the-counter medications and/or herbs) List name and dosage:

____________________________________________________________________________________

____________________________________________________________________________________

Have you ever taken these Medications?

Digitalis yes_______ no_______ unsure_______

Nitroglycerin yes_______ no_______ unsure_______

High Blood Pressure yes_______ no_______ unsure_______

Sedatives yes_______ no_______ unsure_______

Inderal yes_______ no_______ unsure_______

Insulin yes_______ no_______ unsure_______

Pronestyl yes_______ no_______ unsure_______

Vasodilators yes_______ no_______ unsure_______

Other yes_______ no_______ unsure_______

4. EXERCISE HISTORY

Do you exercise? Yes_______ No________

What activity?

____________________________________________________________________________________

How long have you been exercising?

____________________________________________________________________________________

How many days a week do you sprint training?

____________________________________________________________________________________
How many minutes per day?

________________________________________________________________________

Do play in a competitive sport?

________________________________________________________________________

Where do you usually exercise?

________________________________________________________________________

Do you monitor your pulse during your workout?

________________________________________________________________________

5. HEALTH HISTORY

Height ______  Weight ______

Weighed At Age 20 _____  Weighed At Age 30 ____ Weighed At Age 40 ____

Weighed One Year Ago ___  Most Weighed ____  Least Weighed After Age 20 ___

Do you take Vitamin pills? Yes_____  No_____  

List ______________________________________________________________

Approximate your daily intake: Coffee__________  tea__________

coke________ beer________ wine__________ liquor__________

Do you smoke or use tobacco products? Yes_____  No_____  

If yes, approximate your daily usage: Cigarettes______  Cigars_____  Pipes_____

Chewing Tobacco________

Did you ever smoke? Yes_____  No_____  How many years? _______________

Age when you quit________

Approximate the number of hours you work per week? ______________

Vacations weeks per year________________________

Home Status:

Very happy_______  Pleasant_______  Difficult_______  Problem________

________________________________________________________________________

Work Status:

Very happy_______  Pleasant_______  Difficult_______  Problem________

________________________________________________________________________

Do you feel you are stressed? Yes_______  No_______  Unsure______
Are you worried about your health? Yes_______ No_______ Unsure_______

6. APPROXIMATE A TYPICAL 24 HOUR DAY FOR YOU

Number of hours:
_________________________________ Work
_________________________________ TV
_________________________________ Relaxation/Leisure activities
_________________________________ Driving/Riding
_________________________________ Eating
_________________________________ Exercise
_________________________________ Sleep
_________________________________ TOTAL

Additional information from client interview to further assess health/coronary risk status:

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Signature
Date
INTERESTED IN IMPROVING SPRINT TIMES
WITH JUST A SWIG OF CARBOHYDRATE?

http://www.theissnscoop.com/sport-drinks-wash-your-mouth-out-or-not/

A Master’s Student needs participants to test the effectiveness of swirling carbohydrates around in your mouth before sprints. The study will take a total of 3 hours over 3 days.

To qualify:

1) You must already be sprint training or participate in sports that involve bouts of sprinting at least two times a week
2) Must not have high blood pressure or smoke
3) Must not have any metabolic conditions (e.g. diabetes)

If you are interested or have any questions about the project, contact:
Patrick Tomko
Phone: 440-537-7088
Email: ptomko@bgsu.edu
Appendix C. ANNOUNCEMENT

Hey everyone, my name is Pat Tomko, and I am a third-year graduate student here at BGSU. I am looking for participants for my thesis. Dr. Laurent, Dr. Anderson and I are looking to see if there are any benefits in spitting out a sports drink like Gatorade rather than ingesting it. There some claims the sole presence of sports drink in the mouth can enhance performance. We want to see if there is an ideal strategy for rinsing this sports drink in the mouth to maximize sports performance (i.e. sprinting).

However, to be included in the study you must be classified as low risk, according to American College of Sports Medicine (ACSM 2010) guidelines. You cannot have high blood pressure, smoke, or have any type of metabolic disease (such as diabetes) to be included in this study. Also you must also be actively sprint training or participate in a sport that involves brief periods of sprinting at least two days a week. Deciding to either participate or not participate in my study will have no effect on your grade or standing with BGSU. If you have any questions or are interested in participating in this study please feel free to contact me. It is worth noting that contacting me does not mean you are obligated to be in the study, rather it is to only to learn more about the study and what it involves.
Appendix D. FEELING OF AROUSAL SCALE (FAS) (97)

Estimate here how aroused you feel. Do this by pointing to the appropriate number. By “arousal” we meant how “worked-up” you feel. You might experience high arousal in one of a variety of ways, for example as excitement or anxiety or anger. Low arousal might also be experienced by you in one of several different ways, for example as relaxation or boredom or calmness.

1 LOW AROUSAL

2

3

4

5

6 HIGH AROUSAL
Appendix E. ADULT OMNI SCALE OF PERCEIVED EXERTION (RPE) FOR RUNNING

(98)
Appendix F. SESSION RPE (99)

<table>
<thead>
<tr>
<th>Rating</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rest</td>
</tr>
<tr>
<td>2</td>
<td>Very, Very Easy</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat Hard</td>
</tr>
<tr>
<td>5</td>
<td>Hard</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Very Hard</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>Maximum</td>
</tr>
</tbody>
</table>
### Perceived Recovery Status Scale

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Performance Expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Very well recovered / Highly energetic</td>
<td>Expect Optimal Performance</td>
</tr>
<tr>
<td>9</td>
<td>Well recovered / Somewhat energetic</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Adequately recovered</td>
<td>Expect Average Performance</td>
</tr>
<tr>
<td>7</td>
<td>Somewhat recovered</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Not well recovered / Somewhat tired</td>
<td>Expect Weak Performance</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Very poorly recovered / Extremely tired</td>
<td></td>
</tr>
</tbody>
</table>
Appendix H. DIETARY RECORD SHEET

Participant ________________

24-hour food record

Date ________________

Please list all foods and drinks you have consumed during the past 24 hours. Please be as specific as possible and indicate the amount consumed, brand names, and preparation methods like frying, baking, etc.
The Athlete’s Plates are a collaboration between the United States Olympic Committee Sport Dietitians and the University of Colorado (UCCS) Sport Nutrition Graduate Program.
Training volume and intensity vary from day to day and week to week along your training/competition plan. Eating your meals and fueling your workout or race should also be cycled according to how hard or easy it is. Consult with your sport dietitian to put the Athlete’s Plate into practice!

The Athlete’s Plates are tools for you to better adjust your eating to the physical demands of your sport!

EASY  
An easy day may contain just an easy workout or tapering without the need to load up for competition with energy and nutrients. Easy day meals may also apply to athletes trying to lose weight and athletes in sports requiring less energy (calories) due to the nature of their sport.

MODERATE  
A moderate day may be one where you train twice but focus on technical skill in one workout and on endurance in the other. The moderate day should be your baseline from where you adjust your plate down (easy) or up (hard/race).

HARD  
A hard day contains at least 2 workouts that are relatively hard or competition. If your competition requires extra fuel from carbohydrates, use this plate to load up in the days before, throughout, and after the event day.

The Athlete’s Plates are a collaboration between the United States Olympic Committee Sport Dietitians and the University of Colorado (UCCS) Sport Nutrition Graduate Program.
DATE:
August 31, 2016

TO: FROM:
Patrick Tomko  Bowling Green State University Human Subjects Review Board

PROJECT TITLE: SUBMISSION TYPE:
New Project

ACTION: APPROVAL DATE: EXPIRATION DATE: REVIEW TYPE:
APPROVED August 29, 2016 August 28, 2017 Expedited Review

EXPEDITED REVIEW CATEGORY:
Expedited review category # 4

Thank you for your submission of New Project materials for this project. The Bowling Green State University Human Subjects Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

The final approved version of the consent document(s) is available as a published Board Document in the Review Details page. You must use the approved version of the consent document when obtaining consent from participants. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that you are responsible to conduct the study as approved by the HSRB. If you seek to make any changes in your project activities or procedures, those modifications must be approved by this committee prior to initiation. Please use the modification request form for this procedure.
All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must also be reported promptly to this office.

This approval expires on August 28, 2017. You will receive a continuing review notice before your project expires. If you wish to continue your work after the expiration date, your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date.

Good luck with your work. If you have any questions, please contact the Office of Research Compliance at 419-372-7716 or hsr@bgsu.edu. Please include your project title and reference number in all correspondence regarding this project.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Bowling Green State University Human Subjects Review Board's records.
Appendix K. INFORMED CONSENT FOR PARTICIPANT

Informed Consent

Investigator: Patrick Tomko      Email: ptomko@bgsu.edu      Phone: (440) 537-7088
Advisor: Dr. Matt Laurent       Email: cmlaure@bgsu.edu      Phone: (419) 372-6904

Project Title: Carbohydrate Mouth Rinsing: Impact on Fatigue and Recovery from Repeated Sprint Exercise.

Introduction: You are being asked to participate in a study by Patrick Tomko, a student, in the School of Human Movement, Sport, and Leisure Studies and Department of Public and Allied Health, at Bowling Green State University. His advisor Dr. Matt Laurent, is an Associate Professor in the School of Human Movement, Sport, and Leisure Studies at Bowling Green State University.

Purpose: The present study is designed to investigate the effects of carbohydrate (CHO) mouth rinsing (CMR) on fatigue and recovery status during repeated sprints.

Eligibility: To be included in the study you must be 18 years of age or older and you must: 1) already be sprint training or participate in sports or activities that involve bouts of sprinting at least two times a week, 2) must not have high blood pressure or smoke, and must not have any metabolic conditions (e.g., diabetes).

Procedure (Day 1): If you are eligible and choose to participate, you will be asked to come in for a familiarization session where you will read and sign an informed consent form and fill out a medical history questionnaire. The information from the medical history questionnaire will be used to place you into a risk category. Only people considered low risk will be allowed to participate in the study. If you can participate, then you will be asked to perform a practice session where you will be able to familiarize yourself with the equipment and testing procedures. Your height, body mass, and percent body fat will be recorded during the familiarization trial. You will be educated about an appropriate competition diet and how to record it for each testing day. It is important to refrain from consuming caffeine (4 hours before running) and avoid alcohol and intense physical exercise 24 hours before testing.

Each trial will consist of the following:
Day 2

Warm-up
- You will be guided through a warm-up consisting of a 4-minute walk at 3.7 mph, followed by a 2-minute run at 7.5 mph.
- After you walk and run, you will be asked to do 3 sets of 10 toe raises, 20 high knee marches, and 20 butt kicks.
- You will be asked to give a explain you how fatigued you feel using 0-10 scale.

Repeated Sprint Exercise
- You will be asked to rinse a 10% maltodextrin solution in your mouth for 5 seconds and spit it back into a cup.
- You will then be asked to perform six, 35 meter sprints with 10 seconds of recovery between each sprint
- Between each sprint, you will be asked to rate how hard you worked on a 0-10 scale and have your heart rate recorded.
- After you have completed the six sprints, you will be required to rest for 7 minutes seated in a chair.

During this time:

1) You will be asked to rate how hard you worked on a 0-10 scale.
2) You will be asked how you felt after the sprint exercise set using a 1-6 scale.
3) You will have your heart rate recorded.
4) You will have your finger stick via capillary puncture for lactate content.
5) You will be asked to rate how recovered you feel using a 0-10 scale.
- You will complete this protocol two more times.
- After the last set of sprints, you will be seated comfortably for 15-20 minutes, and after that time, you will be asked to rate the difficulty of the entire session.

Day 3:
- You will be asked to come in the next sprint exercise session which will be at least 48 hours after your 1st session and complete another three sets of six, 35 meter sprints following the same procedures with only one difference. Before your first set of six sprints you will be asked to rinse your mouth with a 10% maltodextrin solution for 5 seconds, after the first set you will be asked to rinse for 10 seconds, and then after the second set you will be asked to rinse for 15 seconds. All rinses will be spit back into cup after the rinse time has been completed.

This study will you take a total of three testing days to complete. The familiarization session will take approximately 30 minutes, while each sprint exercise session will take approximately 40 minutes to complete the protocol. All sessions will take place in Eppler South, room 124 or 101.

Voluntary nature: Your participation is completely voluntary. You are free to withdraw at any time. You may decide to discontinue participation at any time without penalty. Deciding to participate or not will not affect your grades or your relationship with Bowling Green State University.

Confidentiality Protection: All data recorded during the study will be stored on a password protected computer. All documents obtained from the subjects will be stored in a locked filing cabinet in a locked office. Only members of the research team will have access to both recorded data and documents during the study. Subject data will be coded to maintain participant confidentiality and kept for three years upon completion of the study.

Risks: The risks of this study are no different than any other high intensity sprinting that you may complete during your training or sporting event. There are potential risks to your health while participating in the study including: 1) cardiovascular injury (heart attack, stroke and death - risk is estimated at <0.01%), 2) Shortness of breath, lightheadedness, dizziness, and nausea, 3) all other possible risks associated with exercise. While there is a risk of a cardiovascular injury, the chance is very low.

The sprinting protocol is very intense; you may become nauseous or lightheaded during or after testing. If you are feeling nauseous or lightheaded, you will be asked to remain in the lab until the symptoms have subsided. If a serious injury does happen, two investigators certified in first aid and CPR will provide immediate care, and an ambulance will be called, if necessary. You will be required to pay for any medical service that may be needed. To avoid any need for medical services, researchers will immediately terminate the testing procedures if you experience chest pain, shortness of breath, wheezing, leg cramps, severe leg pain, light-headedness, confusion, or nausea. If you report or we suspect any of these symptoms during testing, testing will be stopped, and you may no longer take part in the study.

Contact information: If you have any questions, concerns, or comments, you may contact Patrick Tomko at (440) 537-7088, ptomko@bgsu.edu. You may also contact the Chair, Human Subjects Review Board at 419- 372-7716 or hsrb@bgsu.edu, if you have any questions about your rights as a participant in this research.

The investigators in this study would like to thank you for your time and commitment. Without you, this study would not be possible.
I have been informed of the purposes, procedures, risks and benefits of this study. I have had the opportunity to have all my questions answered and I have been informed that my participation is completely voluntary. I agree to participate in this research.

_________________________________________  ________________________________
Participant Signature                              Date