PRE-EXERCISE CARBOHYDRATE SUPPLEMENTATION EFFECTS ON INTERMITTENT CRITICAL VELOCITY, ANAEROBIC RUNNING CAPACITY, AND CRITICAL REST INTERVALS

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ABSTRACT

**Introduction:** Carbohydrates play an important role in human performance. Pre-exercise carbohydrates may have an ergogenic effect in intermittent-based exercise.

**Objectives:** The objectives of the study were to 1) determine if pre-exercise carbohydrate supplementation improves the number of bouts completed by the participants, 2) examine the effects of pre-exercise carbohydrate supplementation on intermittent critical velocity (ICV), 3) examine if pre-exercise carbohydrate supplementation increases anaerobic running capacity (ARC), and 4) determine if pre-exercise carbohydrates improve critical rest intervals (CRI).

**Methods:** Participants (n=13) completed an initial assessment of a graded exercise test (GXT) to measure peak velocity. This velocity was then used to determine velocities for the ICV test protocol. In the ICV test protocol, participants sprint at an equal work-to-rest ratio of 15 seconds at intensities of 130%, 110%, and 120% of their peak velocity until failure. A 15-minute rest period separated each intensity. Each participant completed the protocol twice, while consuming carbohydrates prior to one of the trials. Blood glucose, blood lactate, perceived recovery status (PRS), and session-ratings of perceived exertion (S-RPE) were measured and recorded periodically during testing.

**Results:** Using repeated measures analysis of variance, differences between the baseline and intervention trials regarding ICV, ARC, and CRI were not statistically significant (p=0.823, p=0.653, p=0.778, respectively). However, increases were seen between total distance, time to exhaustion, and number of bouts completed.

**Discussion:** Increases seen in base measures (distance, time, bouts) are indicative of the ergogenic of pre-exercise carbohydrate supplementation.
ACKNOWLEDGEMENTS

A special thank you to my advisors, Dr. Dawn Anderson and Dr. Matt Laurent. I have learned so much from both of you. Your input helped me to develop my thesis. I could not have done this project without your help.

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CHAPTER I

INTRODUCTION

Overview

Carbohydrates and lipids are primary sources of fuel during exercise. These macronutrients are the most readily available to breakdown for energy. Carbohydrates can be broken down for energy faster than lipids. Thus, carbohydrates are used in higher ratios during high intensity, short-duration exercise, while lipids are used more during low intensity, steady-state exercises. As exercise intensity increases, the ratio of macronutrient usage changes increasing the amount of carbohydrate used as compared to the amount of lipid. Carbohydrates are stored in the form of glycogen which can be easily accessed and used for energy with the onset of exercise.

Glycogen goes through the process of glycogenolysis to be converted into glucose. Glycolysis and the TCA cycle eventually convert glucose into adenosine triphosphate (ATP), the primary source of energy. This process takes a quicker approach, whereas lipid metabolism takes longer. Lipids are stored in the form of triglycerides. Triglycerides are composed of three fatty acid chains with a glycerol backbone. Fatty acid chains are removed from glycerol and go to the muscle to be metabolized for energy. Glycerol goes to the liver to be converted into glucose for further energy production.

Carbohydrates can be supplemented before or during exercise to attenuate the usage of stored glycogen, resulting in longer performance capabilities. The supplemented carbohydrate increases glucose availability with in the blood. Sympathetic influence increase glucose uptake utilizing serum glucose initially (1). Increased glucose availability will spare glycogen utilization. Endurance exercise has been the focus of most pre-exercise carbohydrate supplementation.
studies due to the glycogen-sparing effect. Little focus has been designated to short-duration, high-intensity exercise and the relationship with pre-exercise carbohydrate supplementation. This exercise type is increasing in popularity and is more applicable to intermittent sports (rugby, American football, soccer, etc.). Currently, there are no recommendations for carbohydrate intake relating to exercise lasting less than one hour (2).

**Mechanism of Carbohydrate Supplementation**

Research has suggested that carbohydrate ingestion 30-60 minutes prior to exercise may decrease performance capabilities (3–6). Through pre-exercise carbohydrate supplementation, hyperinsulinemia combined with hypoglycemia may occur in some individuals (3,7,8). When carbohydrates enter the body, there is a near instantaneous insulin response (3). This response triggers the storing of glucose by either glucose uptake into cells or by converting glucose to be stored as glycogen or fat. This puts the body into an anabolic state. At the onset of exercise, a state of catabolism is required to quickly breakdown carbohydrates and fats for fuel. However, issues develop because the body is trying to store and breakdown carbohydrates simultaneously. Thus, fats are limited as a source of fuel initially because of the action of insulin. This causes the premature usage of glycogen to fuel the muscle (3). Therefore, the duration for which exercise can be maintained is compromised due to premature usage of glycogen stores.

However, glycogen usage is limited when examining exercise lasting less than one hour (7). An exercise duration of less than an hour will not compromise energy availability. Glycogen stores do not limit exercise capabilities within this time frame. Therefore, pre-exercise carbohydrate supplementation may impact performance when examined during a short duration, high intensity exercise domain. With regards to endurance training, pre-exercise carbohydrate supplementation can limit liver glycogen usage and upregulate glucose into cells (7–10).
Because of this, rebound hypoglycemia may occur. High intensity, short duration exercise performances are impacted differently by carbohydrate supplementation (7). Insulin levels rise in response to increased blood glucose levels. This increases the oxidation of glucose in the skeletal muscle tissues. Increased oxidation is the result of increased activity of the pyruvate dehydrogenase enzyme complex (PDC). The activation of PDC spares phosphocreatine and reduces lactate build up in the muscle (7,11). Because of this, carbohydrate supplementation before high intensity exercise could reduce the onset of fatigue. Glucose can be broken down through glycolysis faster when PDC is upregulated, resulting from carbohydrate supplementation.

Furthermore, carbohydrate consumption interacts with the reward center in the brain (12). Oral receptors are stimulated when carbohydrates are present in the mouth, triggering increased brain activity. In studies involving mouth exposure to carbohydrates, performance improvements have been seen (12).

Critical Power Model

The primary goal of a graded exercise test (GXT), while examining critical power, is to identify the separation of steady-state exercise and non-steady-state exercise (13). Throughout this test, different exercise intensities are experienced and are usually associated with certain thresholds during a GXT. Exercise intensity remains at a moderate level until the lactate threshold is surpassed. Exercise continuing after the lactate threshold is classified as heavy intensity. As exercise approaches maximal oxygen consumption, the severe exercise domain is present. Eventually, the individual will reach volitional exhaustion.

Critical power can be thought of as a threshold, which demarcates the transition between the heavy and severe exercise intensities (13). Below critical power, an individual is in a
steady-state. After passing critical power, the individual is in a non-steady state of exercise and will only be able to exercise for certain duration. Mathematically, critical power is the relationship between power output and time-to-exhaustion (13). This relationship creates an asymptote where the leveling of power indicates the critical power threshold separating exercise domains.

A derivative of the critical power model includes intermittent critical velocity (ICV) and critical rest intervals (CRI). ICV is defined as the sustainable velocity an individual can produce without onset of fatigue (14,15). CRI is defined as duration of rest required to complete repeated exercise (14–16). These derivatives are relevant and specific to intermittent sports. Employing these models can help to improve overall performance and recovery in these athletes. These models incorporate the idea of work to rest ratios, providing relevancy towards intermittent sports. The ICV test yields ICV, CRI, and anaerobic running capacity (ARC). ARC or W’ is recognized as the distance that can be covered during intense exercise by stored energy sources within the body (14,15,17). In this study, carbohydrate supplementation may impact ARC.

Statement of the Problem

Much of the research on sport performance has focused on nutrition during and post exercise. However, adequate and appropriate pre-exercise nutrition has been shown to have positive effects on performance. Specifically, research has been aimed toward carbohydrate ingestion due to its impact in sports. There have been discrepancies in the research regarding pre-exercise carbohydrates and how performance is impacted. Therefore, the purpose of this study is to examine the relationship between pre-exercise carbohydrates and human performance.
Significance of the Problem

Improved performance is desired by athletes within the sporting world. Many athletes have taken drastic measures to maximize their performance. However, these measures may not be effective if the human body is not properly nourished. Since carbohydrates are the driving energy source of performance, this macronutrient must be ingested properly and adequately to maximize performance. Further examination of the appropriate amounts and timing of carbohydrate intake are important when maximizing human performance during high intensity, short duration exercise.

Objectives of the Study

The objectives of this study were to:

1. Determine if pre-exercise carbohydrate supplementation affects the number of sprint sets completed by the participants.
2. Examine the effects of pre-exercise carbohydrate supplementation on CRI.
3. Examine if pre-exercise carbohydrate supplementation affects ARC.
4. Determine if pre-exercise carbohydrate supplementation affects CRI.
CHAPTER II

LITERATURE REVIEW

Carbohydrate Consumption

Multiple studies have examined the concentration of carbohydrate during pre-exercise feedings and the potential effects on exercise performance (3,4,18,19). Consumption amounts ranging from 22 g to 156 g of glucose have been used to evaluate changes in insulin and blood glucose related to each dose (3,4,17,18). Results indicated that a decrease in blood glucose levels occurred regardless of the carbohydrate amount consumed. As a result, it is theorized that carbohydrate consumption has no impact on exercise performance (3,4,18,19). However, this research focused on endurance-based exercise. A study by Galloway et al looked at the effects of carbohydrate concentration on performance during short duration, high-intensity exercise (7). In this study, three concentrations of carbohydrates (0g of carbohydrate (Placebo), 20g/L (2%), and 120g/L (12%)) were consumed prior to performance. Despite not reaching statistical significance, an improvement in performance was observed when 20g/L of carbohydrate was consumed. Therefore, consumption of a specific carbohydrate concentration may be appropriate within the high intensity, short duration exercise domain (7).

Carbohydrate Timing

The timing of carbohydrate intake varies. Multiple studies have indicated that consumption of carbohydrate 15-75 minutes prior to exercise has no effect on performance (3,5,20–23). Ideally, pre-exercise carbohydrate supplementation will raise blood glucose levels without increasing serum insulin levels. Achieving this would not result in rebound hypoglycemia. Brouns et al found that hypoglycemic rebound can be minimized when
carbohydrates are ingested less than ten minutes before exercise (24). Specifically, carbohydrate consumption occurred during the warm up period followed by a break, then the exercise. In this study, the insulin response was reduced, resulting in increased blood glucose levels upon the start of exercise.

These studies examined the effects of pre-exercise carbohydrate supplementation on endurance-based exercise. However, metabolically, high intensity exercise over a shorter time is not dependent on muscle glycogen (7). Therefore, performance is dependent on glucose availability within the shorter time frame. Galloway et al examined the effects of carbohydrate timing and the amount of carbohydrate consumed (7). The results showed a significant improvement in performance when carbohydrate was consumed 30 minutes before exercise. These findings indicate that there may be a specific time for carbohydrate consumption prior to exercise that could produce optimal performance during short duration, high-intensity exercise.

Critical Power Concept

The critical power concept applies to intermittent sports (13). Critical power or critical velocity examines the connection between velocity output and time-to-exhaustion. Furthermore, critical velocity requires consideration of intensity. For example, velocity output can be maintained indefinitely contingent on a minimal exercise intensity. As exercise intensity increases, time-to-exhaustion decreases. Once the lactate threshold has been surpassed, the body will inevitably reach a state of exhaustion (13). The body is no longer able to remove lactate at the rate it is being produced, which will lead to fatigue (25). The critical power concept can be observed as an asymptote. This asymptote represents both steady-state exercise and non-steady-state exercise. Below the asymptote, steady-state exercise is represented; whereas non-steady-state exercise is above the asymptote. For assessment of performance, the critical velocity point
acknowledges when an individual is working beyond the means of the body. Raising the critical velocity point can improve performance due to increased intensity sustainability.

Intermittent Critical Velocity and Critical Rest Intervals

In the critical power concept, a two-component model is presented (14,15,17). The two components, anaerobic and aerobic capacity, are identified as ARC and ICV, respectively, in this study. Several studies have incorporated the ICV concept in order to determine steady-state ICV and CRI (14–17,26). The critical power concept was adapted into an intermittent exercise domain by Morton and Billat (17). This adapted model involved running at supramaximal speeds of 110%, 120%, and 135% of the peak velocity (17). This initial model developed into an equal work-to-rest ratio until exhaustion (14,15). This work-to-rest ratio was completed at velocities of 110%, 120%, and 130%, and of peak volume. This intermittent critical velocity test was validated by Fakuda et al (15). The reliable testing procedure implemented a ten-second work-to-rest ratio at 130%, 110%, and 120% of peak velocity. Between each velocity, a rest period of 15 minutes was implemented so heart rate could return to resting levels.

A study by Price and Moss incorporated perceptual responses into an intermittent exercise protocol (27). Ratings of perceived exertion have been linked to buffering ability of lactate (28). In addition, blood lactate levels have been linked to exercise duration at a certain speed (29,30). As a result of the connections between these phenomena, RPE may have a linkage with exercise length at a certain duration (27). The connection was moderately observed with the intermittent exercise protocol by Price and Moss (27).

The critical power concept was used to derive the idea of CRI. A study by Pereira et al examined the idea using an intermittent vertical jump protocol (16). The purpose of the study was to identify the CRI and apply it to the protocol. Overall, there was a high correlation
between the derived CRI and the outputs using the derived CRI (16). Similarly, Fakuda et al calculated CRI and found a significant positive correlation relating to ARC (14).
CHAPTER III

METHODS

Design

This counterbalanced study examined the effects of pre-exercise carbohydrate supplementation on intermittent critical velocity (ICV), anaerobic running capacity (ARC), and critical rest intervals (CRI) during the ICV test in a repeated measures design. Three trials were conducted in total. The first trial consisted of a graded exercise test (GXT) to identify peak velocity (PV) and peak oxygen consumption (VO$_2$ peak). The next trial provided baseline measures of ICV, ARC, CRI, blood glucose, and blood lactate. The intervention trial followed the same procedures as the baseline trial, except the participants consumed 24g of carbohydrates prior to the ICV test. In total, three visits were required by the participant.

Participants

In this study, the sample was composed of 12 physically active men and one woman that participated in intermittent sports (rugby, football, soccer) or sprint training (Table 1). The individuals were required to be active in a sport or sprint training for a minimum of three days per week. This ensured that the individual participated in high intensity exercise. The participants signed an informed consent document (Appendix A) and completed a physical health questionnaire (Appendix B) prior to testing. The questionnaire is based on the American Colleges of Sports Medicine standards, and assessment criteria provided on the questionnaire were used to assess if the participant met the standards to participate. Participants were excluded if there was a health condition or injury preventing them from performing the requirements of the study.
Recruitment and Consent

Participants for the study were recruited face to face or through e-mail. A researcher recruited participants by giving a recruitment speech to individuals or groups that met the inclusion criteria of the study. An e-mail sent to potential participants including contact information and an electronic copy of the informed consent document. Any questions regarding the study or the consent document could be asked in person or e-mail, and a full understanding of the requirements of the participant was ensured before consent was given.

Table 1. Descriptive statistics of sample\textsuperscript{a} from graded exercise test (GXT)

<table>
<thead>
<tr>
<th>Descriptive</th>
<th>Mean +/- SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>22.31 +/- 1.89</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>179.69 +/- 7.98</td>
<td>165</td>
<td>195</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>92.15 +/- 13.61</td>
<td>69</td>
<td>115</td>
</tr>
<tr>
<td>BMI</td>
<td>28.31 +/- 3.00</td>
<td>22.3</td>
<td>32.7</td>
</tr>
<tr>
<td>% Body Fat</td>
<td>17.45 +/- 6.12</td>
<td>7.8</td>
<td>31.3</td>
</tr>
<tr>
<td>Relative VO2 (ml/kg/m)</td>
<td>45.47 +/- 4.97</td>
<td>33.1</td>
<td>51.8</td>
</tr>
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</table>

\textsuperscript{a}n=13

Nutrition Control

Participants were asked not to consume caffeine four hours prior to any testing trial. In addition, participants needed to refrain from intense exercise 24 hours prior to any trial. For dietary control, participants were asked to replicate their diet before each of the ICV test trials. This limited the variation in carbohydrates in their body between trials. Participants could consume water \textit{ad libitum} throughout all trials.

Anthropometric Measurements

During the first trial, anthropometric measurements and demographic information were obtained. Height (cm) and weight (kg) were recorded using a stadiometer and beam scale.
(Detecto Scale Company, Webb City, MO, USA), respectively. Each participant removed shoes and socks stood with the heels flat against the heel board in an upright position. Body composition was measured using bioelectrical impedance (InBody 230, InBody CO, Cerritos, CA, USA). This method has been validated for measuring body composition (31).

Pre-exercise Carbohydrate

Carbohydrates were consumed by the participant immediately prior to the standardized warm-up procedure only for the intervention trial. Before the baseline trial, no carbohydrate supplement was consumed. The carbohydrates were in the form of a gel (Clif Bloks Energy Chews, Clif Bar & Company, Emeryville, CA, USA), and 24g of carbohydrates were consumed by each participant (Appendix D).

Standardized Warm-Up Procedures

Standardized warm-up procedures were completed by the participant prior to each trial of the intermittent critical velocity test (32). Participants were fitted with a Polar heart rate monitor prior to warm-up (Polar Electro, New York, USA). The participants walked for four minutes at 3.7 miles per hour on a motorized treadmill, followed by two minutes of running at 7.5 miles per hour as part of the standardized warm-up procedures. Three sets of 10 repetitions of active stretching consisting of calf raises, high knees, and butt kicks were performed immediately following the motorized treadmill activity.

Graded Exercise Test (GXT)

An automated metabolic system (Parvo TrueOne; ParvoMedics, Sandy, UT, USA) was used to measure gas exchange during the GXT. This system was calibrated to standard temperature, pressure, and humidity as suggested by the manufacturer. Volume was calibrated
using a 3-L calibration syringe (Rudolph Volume Calibration Syringe, Hans-Rudolph, Shawnee, KS, USA) and gases of known concentration. The GXT was performed to volitional exhaustion on a motorized treadmill using a protocol by Peake et al (33). In this protocol, initial velocity was 10 km/h at a 0% grade. The velocity was increased by two km/h at two-minute increments until a velocity of 16 km/h was reached. After this, velocity was increased by one km/h per minute until 18 km/h. A gradient increase of 2% was added each minute until volitional exhaustion was achieved. During the test, oxygen consumption (VO₂; L/min), Respiratory Exchange Ratio (RER), and heart rate (bpm) were recorded. VO₂ peak was designated as the highest 15-second value for oxygen consumption the last minute of the test.

**Intermittent Critical Velocity Test**

Intermittent sprints of 15 seconds were completed in a 1:1 work-to-rest ratio until exhaustion on a treadmill. Three sets of intermittent sprints at velocities of 130%, 110%, and 120% of PV were separated by 15 minutes of rest (14,15). Each set of intermittent sprints was timed and recorded. Exhaustion was identified as the inability to maintain the velocity or by the participant grasping the handrails to indicate exhaustion. Participants were given verbal encouragement by the researchers present. Throughout the intermittent sprint sets, total distance covered, total running time, total test time, and the number of bouts completed were measured and recorded (15). These values were used in the linear, total distance model (L-TD) and linear regression to develop ICV and ARC (34–37). The L-TD model is recognized as:

\[ TD = ARC + ICV \times t \]

TD represents total distance (time x velocity) and \( t \) equals the time to exhaustion. Within this model, ICV is the slope in linear regression and ARC is the y-intercept. This concept was
derived from Fukuda et al (15). CRI can be calculated using a similar idea from a concept by Pereira et al (16). The CRI equation is as follows:

$$CRI = \frac{TD / \sum INT}{ICV_{CRI}}$$

In this model, TD represents total distance (time x velocity). This value is divided by the number of completed intervals. ICV\textsubscript{CRI} represents the slope of a linear regression equation derived from total distance and total test time (16).

Heart Rate, Blood Glucose, and Blood Lactate

Heart rate was recorded before and after each sprint of the ICV test. Blood glucose levels were measured and recorded at six points throughout each trial via capillary puncture. The first of these measurements was prior to ingestion of the carbohydrate supplement, which served as a baseline. Blood glucose was then collected before the first exhaustive test and then after each exhaustive test, as well as following the 15-minute rest period for a final blood glucose measure. These collections were necessary to monitor blood glucose levels throughout the exercise protocol, as well as to evaluate the effects of the carbohydrate supplement on blood glucose levels. Blood lactate was measured at each point of the blood glucose collection. These measurements were used to assess the work being done by individual.

Perception

Areas of perception were documented throughout the trials. Session Rating of Perceived Exertion Scale (Appendix E) (S-RPE) were used to assess the overall effort given throughout the entire ICV test protocol (38). S-RPE was obtained regarding the overall difficulty of each sprint set. This scale ranges from zero to ten, where zero is minimal effort and ten is maximal effort. Before the second and third sprint sets, the Perceived Recovery Scale was used to assess the
feeling of recovery (Appendix F) (39). This scale ranges from zero to ten, where zero is minimally recovered and ten is maximally recovered.

Statistical Analysis

ICV, ARC, and CRI were calculated using linear regression and the L-TD model for each ICV test. These values were compared between the baseline and intervention trials using repeated-measures analysis of variance. Additionally, comparisons were made between PRS, SRPE, blood glucose, blood lactate, and overall total time, overall total distance, and overall number of bouts. Significance was assessed at a p-value of $\leq 0.05$. Data was analyzed using SPSS Version 20.0 (SPSS, Inc., Chicago, IL, USA).
CHAPTER IV

RESULTS AND DISCUSSION

Means and standard deviations of overall measures collected during both the baseline trial and the intervention trial to determine the effect of pre-exercise carbohydrate supplementation are listed in Table 2. Although not statistically significant, increases were seen in total distance, time to exhaustion, and number of bouts completed. These measures were used to calculate intermittent critical velocity (ICV), anaerobic running capacity (ARC), and critical rest interval (CRI) using the linear, total distance model (34–37). Similarly, increases in ICV, ARC, and CRI occurred; however, were not significant.

Table 2: Descriptive statistics\textsuperscript{a} of overall measures between baseline and intervention trials of ICV test to determine the effect of pre-exercise carbohydrate supplementation.

<table>
<thead>
<tr>
<th>Overall Measure</th>
<th>Baseline</th>
<th>Intervention</th>
<th>P value</th>
</tr>
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<tbody>
<tr>
<td>Distance (m)</td>
<td>2874.60 +/- 744.59</td>
<td>3165 +/- 800.44</td>
<td>0.164</td>
</tr>
<tr>
<td>Total Time (s)</td>
<td>1075.38 +/- 403.58</td>
<td>1172.31 +/- 380.95</td>
<td>0.152</td>
</tr>
<tr>
<td>Bouts</td>
<td>35.92 +/- 13.41</td>
<td>39.08 +/- 12.70</td>
<td>0.107</td>
</tr>
<tr>
<td>ICV\textsuperscript{b} (m/s)</td>
<td>4.51 +/- 0.37</td>
<td>4.54 +/- 0.04</td>
<td>0.823</td>
</tr>
<tr>
<td>ARC\textsuperscript{c} (m)</td>
<td>160.50 +/- 59.51</td>
<td>173.36 +/- 79.27</td>
<td>0.653</td>
</tr>
<tr>
<td>CRI\textsuperscript{d} (s)</td>
<td>36.31 +/- 2.81</td>
<td>36.75 +/- 4.66</td>
<td>0.778</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Mean +/- SD, n = 13
\textsuperscript{b}ICV = Intermittent Critical Velocity
\textsuperscript{c}ARC = Anaerobic Running Capacity
\textsuperscript{d}CRI = Critical Rest Interval

These results indicate there may be improvement in performance from pre-exercise carbohydrate supplementation despite lacking significance. A larger sample size may have
yielded a greater difference between trials. Once these values are standardized mathematically, the differences decrease marginally. Similar results were seen by Galloway et al. (2014) while examining the effects of timing and concentration of pre-exercise carbohydrates on performance (7). Performance increased significantly related to the timing of intake, and improved regarding carbohydrate concentration, although not significantly. Timing of intake was comparable to this study, as the time between consumption and performance was approximately 20 minutes. Regarding concentration, this study used a carbohydrate concentration of 24g of carbohydrate, while Galloway et al implemented a 32g carbohydrate concentration (7). This difference may have impacted the performance negatively, as the carbohydrates may have been used too quickly to sustain the length of the test. Future research could implement a larger carbohydrate concentration or a spectrum of concentrations to further understand appropriate carbohydrate concentrations for improved human performance.

Blood glucose and blood lactate samples were collected throughout each testing session (n=12). One participant opted out of the blood glucose and blood lactate measures. Blood glucose and blood lactate levels were not significantly different from each other at each sample collection (p>0.05). The change of each of these blood glucose and blood lactate collections is represented in Figure 1 and Figure 2, respectively.

Blood glucose comparisons between baseline and intervention trials indicated a lack of hypoglycemic effect when carbohydrates were supplemented. Upon the initiation of exercise, there was an uptake of glucose into the muscle, which may lead to lower blood glucose levels (3). Carbohydrate supplementation seemed to have blunted this decrease, maintaining and slightly increasing blood glucose. Blood glucose maintenance may also maintain the supply of
glucose to the brain (3). Additionally, this increase in blood glucose may provide additional substrate to the muscle, enabling more glucose uptake. Both may pertain to human performance.

Figure 1: Comparison of blood glucose changes during baseline and intervention trials of the effect of pre-exercise carbohydrate supplementation on the intermittent critical velocity test.
Interestingly, a sharp decline in blood glucose immediately following the third session of the trial, followed by a peak in blood glucose at the final measurement was observed. The decline could be representative of the complete usage of the carbohydrate supplement. Carbohydrate supplementation has been shown to delay hepatic glucose production (3). Therefore, as the substrate was depleted, the decline in blood glucose followed by a sharp rise could indicate the delay between substrate utilization and hepatic glucose production. Alternatively, Benton (1990) describes a relationship between blood glucose and psychological functioning (40). It could be proposed that the body was preparing for recovery of glucose stores in muscle tissues. As the participants were aware of the conclusion of testing, the brain could have been informing the body that sustained recovery was beginning, resulting the rise in blood glucose levels.
Results of the blood lactate measures follow the pattern of the intensity of the test. The intervention trial elicited higher levels of blood lactate accumulation when compared to the baseline trial. This would suggest that carbohydrate supplementation would promote improved performance, potentially through the method of delaying the onset of fatigue. Carbohydrates have been shown to stimulate the pleasure center in the brain (12). This stimulation overrides the pain stimulus introduced by exercise. Therefore, the individual would be desensitized to exercise, resulting in higher blood lactate concentrations.

The results of this study are also indicative of the relationship between the difficulty of the exercise and the lactate produced as a byproduct as seen by the pattern of blood lactate concentrations related to the exercise design. The initial intensity of 130% saw the highest lactate accumulation most likely because of insufficient oxygen supply to the muscle. With oxygen insufficiency, glucose utilization is incomplete, resulting in elevated lactate concentrations. Similarly, across the 110% and 120% intensities, less lactate accumulation occurred as oxygen was better sufficiently supplied to the body. However, more lactate accumulated during the 120% compared to the 110%.

Perceptual measures of Perceived Recovery Status (PRS) and Session Rating of Perceived Exertion (S-RPE) were collected during testing (n=13). The comparison of these measures yielded a significant difference between trials in PRS prior to beginning the 110% session of the ICV test (p=0.028). The intervention trial had a significantly lower PRS rating than the baseline trial. No other perceptual measures were significantly different between baseline and intervention trials. The comparison of the perceptual changes is presented in Table 3.
Table 3. Analysis of PRS\textsuperscript{a} and S-RPE\textsuperscript{b} between baseline and intervention trials of ICV\textsuperscript{c} test due to the effect of pre-exercise carbohydrate supplementation. \#

<table>
<thead>
<tr>
<th>PRS</th>
<th>Baseline</th>
<th>Intervention</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>8.38 +/- 1.26</td>
<td>8.31 +/- 1.03</td>
<td>0.808</td>
</tr>
<tr>
<td>Before 110%</td>
<td>6.46 +/- 1.13</td>
<td>5.92 +/- 0.95</td>
<td>0.028*</td>
</tr>
<tr>
<td>Before 120%</td>
<td>5.54 +/- 1.51</td>
<td>5.31 +/- 1.44</td>
<td>0.534</td>
</tr>
<tr>
<td>Final</td>
<td>4.69 +/- 1.49</td>
<td>4.62 +/- 1.61</td>
<td>0.673</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S-RPE</th>
<th>Baseline</th>
<th>Intervention</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 130%</td>
<td>7.85 +/- 1.14</td>
<td>7.85 +/- 1.14</td>
<td>1.000</td>
</tr>
<tr>
<td>After 110%</td>
<td>6.46 +/- 1.66</td>
<td>6.69 +/- 1.32</td>
<td>0.513</td>
</tr>
<tr>
<td>After 120%</td>
<td>8.08 +/- 1.19</td>
<td>8.15 +/- 1.07</td>
<td>0.673</td>
</tr>
<tr>
<td>Total Test</td>
<td>8.08 +/- 1.12</td>
<td>8.38 +/- 0.65</td>
<td>0.337</td>
</tr>
</tbody>
</table>

\textsuperscript{a}PRS = Perceived Recovery Status  
\textsuperscript{b} S-RPE = Session Rating of Perceived Exertion  
\textsuperscript{c}ICV = Intermittent Critical Velocity

The results of the study indicate that participants felt significantly less recovered following the 130% intensity session of the ICV test in the intervention trial compared to the baseline trial. This may suggest that carbohydrate supplementation has a negative influence on one’s perception of recovery. However, carbohydrates have been shown to, as previously mentioned, stimulate the reward centers, which may lead to increased performance (12). Therefore, it may be viewed that the carbohydrate supplement increased the work completed in this session, eliciting a feeling of lower recovery.

Furthermore, outputs of distance, time to exhaustion, and the number of bouts completed were higher in the intervention trial compared to the baseline trial (Table 4), yet there was no significant change in S-RPE between the intervention and baseline trials. This shows an
ergogenic effect of the pre-exercise carbohydrate supplements as more work was completed with the same perceived exertion.

Table 4. Comparison of distance, time to exhaustion, and number of bouts at each intensity between baseline and intervention trials of ICV\(^{a}\) test due to the effect of pre-exercise carbohydrate supplementation.*

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Measure</th>
<th>Baseline</th>
<th>Intervention</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>130%</td>
<td>Bouts</td>
<td>8.46 +/- 3.02</td>
<td>9.00 +/- 2.97</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Total Distance (m)</td>
<td>753.98 +/- 186.86</td>
<td>805.96 +/- 193.85</td>
<td>0.188</td>
</tr>
<tr>
<td></td>
<td>Time to Exhaustion (s)</td>
<td>253.85 +/- 90.51</td>
<td>270.00 +/- 89.16</td>
<td>0.17</td>
</tr>
<tr>
<td>110%</td>
<td>Bouts</td>
<td>18.23 +/- 7.75</td>
<td>20.62 +/- 7.88</td>
<td>0.198</td>
</tr>
<tr>
<td></td>
<td>Total Distance (m)</td>
<td>1384.03 +/- 437.79</td>
<td>1582.14 +/- 528.89</td>
<td>0.186</td>
</tr>
<tr>
<td></td>
<td>Time to Exhaustion (s)</td>
<td>546.92 +/- 232.43</td>
<td>618.46 +/- 236.39</td>
<td>0.198</td>
</tr>
<tr>
<td>120%</td>
<td>Bouts</td>
<td>9.15 +/- 3.26</td>
<td>9.69 +/- 2.81</td>
<td>0.205</td>
</tr>
<tr>
<td></td>
<td>Total Distance (m)</td>
<td>740.30 +/- 183.72</td>
<td>798.55 +/- 186.70</td>
<td>0.092</td>
</tr>
<tr>
<td></td>
<td>Time to Exhaustion (s)</td>
<td>274.62 +/- 97.86</td>
<td>290.77 +/- 84.31</td>
<td>0.205</td>
</tr>
</tbody>
</table>

\(^{a}\)ICV = Intermittent Critical Velocity
CHAPTER V

SUMMARY AND CONCLUSIONS

Carbohydrates have been shown continuously in research to positively impact human performance. However, it is still unclear regarding the ideal concentration and timing of carbohydrate intake for optimal performance. This study sought to further understand how pre-exercise carbohydrate consumption affects intermittent critical velocity (ICV), anaerobic running capacity (ARC), and critical rest interval (CRI) by means of the ICV test protocol. The participants (n=13) completed the ICV test protocol twice, one trial as a baseline of comparison and the other as an intervention trial where 24g of carbohydrates were consumed prior to testing. Despite lacking statistical significance, improvements were seen in distance, time to exhaustion, and the number of bouts completed, while maintaining no significant difference in perceived exertion. Each of these improvement areas indicates that pre-exercise carbohydrates may have an ergogenic effect.

A limitation to this study is the sample size. Many of the comparisons made between the baseline and intervention trials were trending toward significance. Compared to other studies, the sample size in this study was considerably smaller. Therefore, a larger sample size may have produced significant results.

Future research regarding pre-exercise carbohydrates could examine a spectrum of concentrations to assess an appropriate concentration to elicit significant performance improvement. A ratio of carbohydrates to anthropomorphic measures could be most appropriate to provide an individual formula.
REFERENCES


APPENDIX A

Informed Consent

Investigator: Adam Bialecki  Email: abialec@bgsu.edu  Phone: (419) 205-8320
Advisors: Dr. Matt Laurent  Email: cmlaure@bgsu.edu  Phone: (419) 372-6904

Project Title: PRE-EXERCISE CARBOHYDRATE SUPPLEMENTATION EFFECTS ON INTERMITTENT CRITICAL VELOCITY, ANAEROBIC RUNNING CAPACITY, AND CRITICAL REST INTERVALS

Introduction: You are being asked to participate in a study by Adam Bialecki, 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. The present study is designed to examine the effects of pre-exercise carbohydrate supplementation on performance via the intermittent critical velocity testing.

Purpose: Pre-exercise carbohydrate intake has been limited throughout research within a high intensity, short duration exercise mode. However, there may be a relationship between amount and timing of carbohydrate intake on human performance within this type of exercise. The intermittent critical velocity test can measure the maximum velocity that can be continuously achieved with specific work to rest ratios. Also, assessment of adequate rest time can determine the least amount of rest time needed to achieve critical velocity. Pre-exercise carbohydrate supplementation may be a strategy for improving performance by means of intermittent critical velocity analysis.

Eligibility: To be included in the study you must be 18 years of age or older and you must: 1) participate in repeated high-intensity sprints and/or intermittent based sport training at least three days per week, 2) must not have high blood pressure or smoke, and must not have any metabolic conditions (e.g. diabetes), 3) must not have an allergy to the carbohydrate supplement (Clif Bar & Company, CLIF BLOKS Energy Chews, Strawberry, Emeryville, CA, USA), and must be able to consume the supplement.

Procedure: If you are eligible and choose to participate, you will be asked to perform a graded exercise test on a motorized treadmill after signing an informed consent document and completing 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 are able to participate, your height, body mass, and percent body fat will be recorded. It is important to refrain from intense physical exercise 24 hours before testing and caffeine four hours before testing. Before each session, dietary intake must be replicated to the best of your ability to ensure consistency. Following the graded
You will be able to familiarize yourself with the equipment and testing procedures. The familiarization will include practice mounting and dismounting a treadmill with the belt in motion.

**Standardized Warm-up**

This warm-up will be done before each session. During the graded exercise test/familiarization session, this warm-up will be demonstrated for you to ensure procedures are correct.

- 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 at 63 beats per minute.

**Day 1: Graded Exercise Test/Familiarization**

An automated metabolic system (Parvo TrueOne; ParvoMedics, Sandy, UT, USA) will be used to measure gas exchange during the graded exercise test (GXT).

- Initial velocity is at 6.2 mph with 0% grade.
- Velocity is increased by 1.2 mph every two minutes until 10 mph
- Velocity is increased by 0.6mph per minute until 11.2 mph
- Gradient is increased by 2% each minute until volitional exhaustion.
- 15-minute rest period after GXT
- Mount and dismount practice on motorized treadmill until the participant is comfortable with the procedure.

**Day 2/ Day 3: Intermittent Critical Velocity Test**

Each trial will consist of the following:

**Intermittent Critical Velocity Test**

- Blood glucose will be measured prior to carbohydrate supplement ingestion
- You will be asked to consume 24g of carbohydrates immediately prior to the standardized warm-up.
- After the warm-up, your blood glucose levels will be measured and recorded
- Intermittent sprints of 15 seconds will be completed in a 1:1 work to rest ratio until exhaustion on a treadmill. Three sets of intermittent sprints at velocities of 130%, 110%, and 120% of peak velocity, determined from the maximal test from day 1, will be separated by 15 minutes of rest.
- During this time:
  1) You will have your heart rate recorded.
  2) You will have your finger stick via capillary puncture for lactate and blood glucose content.
  4) You will be asked to rate how hard you worked on a 0-10 scale.
  5) You will be asked to rate how recovered you feel using a 0-10 scale.

All procedures will be followed identically between the 2 sessions excluding the intake of 24g of carbohydrate prior to the standardized warm-up.

This study will you take a total of three testing days to complete. The graded exercise test session will take approximately 40-60, while each intermittent critical velocity test session will take approximately 90 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 course of 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 exercise 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 graded exercise test and intermittent critical velocity test will require maximal effort; 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. In an attempt 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.

**Benefits:** By participating in this study, information about your performance will be provided after completion. This will include the body composition analysis results, individual intermittent critical velocity, individual anaerobic running capacity, and personal critical rest interval. Intermittent critical velocity is the maximum velocity at which you can reach repeatedly. Anaerobic running capacity refers to the total duration at which you could maintain intermittent sprints. Critical rest interval refers to the shortest rest period that you need in order to achieve maximum velocity. This information will benefit you by furthering your understanding of your own performance at a maximal, intermittent level.

**Contact information:** If you have any questions, concerns, or comments, you may contact Adam Bialecki at (419) 205-8320, abialec@bgsu.edu, or Matt Laurent at cmlaure@bgsu.edu. You may also contact the Chair, Human Subjects Review Board at (419) 372-7716 or hsr@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 __________________________
APPENDIX B

Health Screening Questionnaire

Fitness Center Preparticipation Screening Questionnaire

Assess your health needs by marking all true statements.

History
You have had:
  ___ A heart attack
  ___ Heart surgery
  ___ Cardiac catheterization
  ___ Coronary angioplasty (PTCA)
  ___ Pacemaker/implantable cardiac defibrillator/rhythm disturbance
  ___ Heart valve disease
  ___ Heart Failure
  ___ Heart transplantation
  ___ Congenital heart disease

Symptoms
  ___ You experience chest discomfort with exertion.
  ___ You experience unreasonable breathlessness.
  ___ You experience dizziness, fainting, blackouts.
  ___ You take heart medications.

Other health issues
  ___ You have diabetes
  ___ You have asthma other lung disease.
  ___ You have burning or cramping in your lower legs
      when walking short distances.
  ___ You have musculoskeletal problems that limit your physical activity
     —— You have concerns about the safety of exercise.
     —— You take prescription medication(s)
     —— You are pregnant
Cardiovascular risk factors

___ You are a man older than 45 years.
___ You are a woman older than 55 years, you have had a hysterectomy, or you are postmenopausal.
___ You smoke, or quit within the previous 6 mo.
___ Your blood pressure is greater than 140/90.
___ You don’t know your blood pressure.
___ You take blood pressure medication.
___ Your blood cholesterol level is >200 mg/dL.
___ You don’t know your cholesterol level.
___ You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
___ You are physically inactive (i.e., you get less than 30 min. of physical activity on at least 3 days per week).
___ You are more than 20 pounds overweight

___ None of the above is true.

If you marked two or more of the statements in this section you are required to obtain a physicians release, attached, in order to join the facility.

You should be able to exercise safely without consulting your physician or other healthcare provider in a self-guided program or almost any facility that meets your exercise program needs.
Hi everyone, my name is Adam Bialecki, and I am a second year graduate student conducting my thesis involving critical power output (sprinting) and pre-exercise carbohydrate supplementation. Evidence has shown that consuming carbohydrate in a specific window prior to exercise may improve performance.

I am in need of individuals that participate in sprint training or intermittent based sports three times per week. In order to be included in the study, you must meet the American College of Sports Medicine (ACSM) guidelines. Requirements are that you cannot have high blood pressure, smoke, or any metabolic diseases, such as diabetes. Participation in my study would require a total of three visits to Eppler South, room 124 or 101. If you choose to participate, your participation will not affect your relationship or grade with BGSU. If you are interested, please feel free to contact me if you are interested or have any further questions regarding my study.

- My contact information will be given following the presentation.
APPENDIX D
Carbohydrate Supplement Information

Carbohydrate Supplement Nutrition Information: Clif Bar & Company, CLIF BLOKS Energy Chews, Strawberry, Emeryville, CA, USA

<table>
<thead>
<tr>
<th>Nutrition Facts</th>
<th>Amount/Serving</th>
<th>%DV*</th>
<th>Amount/Serving</th>
<th>%DV*</th>
<th>Amount/Serving</th>
<th>%DV*</th>
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</thead>
<tbody>
<tr>
<td>Serv. Size</td>
<td>3 Pieces (30g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calories</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calories from Fat</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

*Percent Daily Values (DV) are based on a 2,000 calorie diet

### Session Rating of Perceived Exertion (Foster 2001)

<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>
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</table>
### Perceived Recovery Status Scale

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Very well recovered / Highly energetic</td>
<td>Expect Improved Performance</td>
</tr>
<tr>
<td>9</td>
<td>Well recovered / Somewhat energetic</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Moderately recovered</td>
<td>Expect Similar Performance</td>
</tr>
<tr>
<td>7</td>
<td>Adequately recovered</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Somewhat recovered</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Not well recovered / Somewhat tired</td>
<td>Expect Declined Performance</td>
</tr>
<tr>
<td>4</td>
<td>Very poorly recovered / Extremely tired</td>
<td></td>
</tr>
</tbody>
</table>
DATE: February 20, 2017
TO: Adam Bialecki
FROM: Bowling Green State University Institutional Review Board
PROJECT TITLE: [965697-2] PRE-EXERCISE CARBOHYDRATE SUPPLEMENTATION EFFECTS ON INTERMITTENT CRITICAL VELOCITY, ANAEROBIC RUNNING CAPACITY, AND CRITICAL REST INTERVALS
SUBMISSION TYPE: Revision
ACTION: APPROVED
APPROVAL DATE: February 17, 2017
EXPIRATION DATE: January 19, 2018
REVIEW TYPE: Expedited Review
REVIEW CATEGORY: Expedited review category # 7

Thank you for your submission of Revision materials for this project. The Bowling Green State University Institutional 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.

Reviewer Comment: The PI indicates that only men will be recruited for the study, however, in the response to modifications requested the PI indicated "he/she has no allergy to the supplement". Is it true that only men will be recruited for the study?

Please note that you are responsible to conduct the study as approved by the IRB. 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 January 19, 2018. 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 orc@bgsu.edu. Please include your project title and reference number in all correspondence regarding this project.