Research Article
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Acute carbohydrate loading on anaerobic threshold and VO_2 max in active college aged individuals

Abstract

Carbohydrate (CHO) loading is believed to be an ergogenic dietary asset for aerobic performance by maximizing CHO oxidation and to combat glycogen depletion within the working muscle cells. However, evidence-based research has displayed that an increase in fat metabolism, subsequently lower CHO oxidation, may provide sufficient energy during submaximal and maximal exertion through beta oxidation.For this reason, active volunteers were recruited to undergo a double-blind study to determine if an acute carbohydrate loading dietary supplement was effective in enhancing performance on a maximal oxygen uptake (VO_2) test.Eleven college aged (22.09±1.3) students (male n=8, female n=3) participated in this double-blind randomized study. Subjects consumed either a CHO (1g/kg body weight) or placebo supplement followed by a 12 hour fast. Following this fast, first testing session consisted of a seven-point skin caliper for body composition (% body fat), fasting blood glucose as measured by point of care finger stick method using Abbott Precision blood glucose meter (mg/dL), and a VO_2 max test (mL/kg/min) measured by a modified Tread Sport Treadmill Protocol. Prior to the second test date, the subject consumed either CHO supplement or placebo, followed by 12 hour fast. Second test day consisted of fasting blood glucose, and VO_2 max test. Protocols were matched for the second bout of testing.A paired samples t-test (SPSS v.26) was conducted to determine significance ($p \leq 0.05$) on each of the four variables: VO_2 max, fasting blood glucose (GLU), anaerobic threshold (AT), and respiratory quotient (RQ). No significant differences were found when comparing groups on all variables (VO_2 $p=0.923$,GLU $p=0.099$,AT $p=0.641$, RQ $p=0.372$). Acute CHO loading has no significant impact on performance variables as defined by AT, RQ, and VO_2 max.

Keywords: carbohydrate loading, VO2 max, fat oxidation, anaerobic threshold, sports performance, metabolic flexibility

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Randy Wolf,[1] Cole Smith,[2] Chris Carroll PhD[3]

[1,2,3]Department of Human Kinetics and Applied Health Science, Bethel University, USA

Correspondence: Cole Smith, Bethel University, 3900 Bethel Drive, St. Paul, MN, USA, 970-618-4874, Email cos97764@bethel.edu

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Abbreviations: CHO, carbohydrate; AT, anaerobic threshold; GLU, fasting blood glucose; RQ, respiratory quotient; IF, intermittent fasting; IR, insulin resistance; MetS, metabolic syndrome, MetF, metabolic flexibility

Introduction

As an athlete, the ability to compete and perform at a higher level, has never been more important. The desire to find a competitive edge, continues to push science and its understanding of the body's physiology.

Maximal exertion VO_2 max tests, are strenuous exercise tests that quickly depletes energy sources within the body, namely, readily available blood glucose and muscle glycogen[1] through aerobic metabolism and anaerobic glycogenolysis.While the VO_2 max test is primarily an aerobic measure, nonetheless, during this intense exercise, glycolytic metabolism does contribute to the total energy expenditure during maximal exertion.[2] As such, the importance of readily available substrates to produce energy is paramount. Traditionally, carbohydrate (CHO) serves as an ergogenic aid, to prevent glycogen depletion and provide readily available glucose to the working muscle cell,[3] to go through the necessary aerobic and glycolytic metabolic processes. Traditional research suggests there is a direct correlation between muscle performance/fatigue and glycogen storage within the glucose dependent individual.[1] These were found to be fundamental findings within the world of sports physiology.[1] While well chosen nutrition has shown to aid in performance and recovery, it is also well known that nutritional goals and requirements are not static.[4]

Evidence-based research demonstrates that increased fat oxidation, subsequently lower CHO oxidation, can provide the necessary energy during submaximal and maximal exertion through beta-oxidation.[5] The human body has been proven to adapt and tap into fat stores to oxidize fat through beta-oxidation when CHO substrates are no longer available. This is accomplished through adapting to a high-fat diet[6] or more acutely, with intermittent fasting (IF), both forms to obtain MetF.[7] Moreover, endurance athletes adapting to high-fat diets found no decrease in endurance performance,[8] a finding that is not new to the scientific community.[9] Furthermore, the consumption of habitual and high CHO diets can lead to adverse health effects such as insulin resistance (IR), Metabolic Syndrome (MetS),[10] that stem from hyperinsulinemia, a common finding in CHO rich diets.

The present study focused its attention on the acute consumption of CHO (1g/kg body weight), 12 hours prior to performing a VO_2 max test, a form of CHO loading. Specifically, with the goal of assessing performance on VO_2 max as measured by anaerobic threshold (AT), Respiratory Quotient (RQ), and VO_2 max.

Methods

Eleven college aged (22.09±1.3) students (male n=8, female n=3) from Bethel University, who met the inclusion/exclusion criteria, and ACSM guidelines, were chosen to participate in this double-blind randomized study. The ACSM guidelines consist of 150 minutes of moderate-intensity per week of exercise in the past three months.

Following consent, subjects were randomly assigned and consumed either a CHO (1g/kg body weight)[4] or placebo supplement followed by a 12 hour fast. Followed by a 12 hour fast, the first testing session consisted of a seven-point skin caliper for body composition (% body fat), fasting blood glucose as measured by point of care finger stick method using Abbott Precision blood glucose meter (mg/dL), and a VO_2 max test (mL/kg/min) measured by a modified Tread Sport Treadmill Protocol. Prior to the second test date, the subject consumed either CHO supplement or placebo (depending on which drink the subject had consumed in the first testing session), followed by 12 hour fast. Second test day consisted of fasting blood glucose, and VO_2 max test. Protocols were matched for the second bout of testing. Subjects completed both testing dates within a 7 day time period, with a required 48 hour break between the first and second test dates.

Inclusion criteria

- Must be between the ages of 18 and 24 years
- Must be currently active according to ACSM standards of 30 minutes of moderate intensity activity on at least 3 days per week for the last 3 months
- Must complete the Informed Consent
- Must receive clearance for exercise testing based on Exercise Preparticipation
- Health Screening Questionnaire for Exercise Professionals (adapted from ACSM's Guidelines for Exercise Testing and Prescription)
- Must be able to attend two appointments lasting approximately one hour each

Exclusion criteria

- Any individual who does not submit to the informed consent
- Any individual under the age of 18 or above the age of 24 will not be allowed to participate in this study, as they do not meet the specified inclusion age range.
- Any individual deemed high risk (one or more symptoms or a diagnosed condition) according to the Exercise Preparticipation Health Screening
- Questionnaire for Exercise Professionals and who doesn't obtain signed clearance documentation from a licensed physician.

Fasting blood glucose

Subjects were asked to fast for 12 hours after ingesting CHO supplement or placebo prior to performing both test days. This test will be used to assess the levels of glucose present in the subjects blood. This will be an indicator to see how insulin is reacting within the body and to determine what is occurring at a cellular level. First, their finger was sanitized with an alcohol swab; then, a lancet was used to prick the finger to allow the finger to bleed. After the blood appears, a droplet was placed on the blood glucose testing strip to read the content of sugar present in the blood.

Jackson/ Polluck 7-point skin caliper

The skin-fold technique is a non-invasive method used to determine body composition. Subcutaneous fat folds were measured using a caliper at seven sights on the subject. These measurements were entered into a spreadsheet that calculate lean body mass and fat body mass. The seven locations of the body that the clinician measured with the caliper were the tricep, which is a vertical fold at the midpoint of the posterior side of tricep between shoulder and elbow with arm relaxed at the side. Chest, which is a diagonal fold half the distance between anterior axillary line and the nipple. Subscapular, which is a diagonal fold 2cm from the inferior angle of the scapula. Midaxillary, which is at the midaxillary line horizontal to xiphoid process of the sternum. Abdominal, which is a vertical fold 2 cm to the right of the navel. Suprailiac, which is a diagonal fold parallel and superior to the iliac crest. Thigh, which is the midpoint of the anterior side of the upper leg between the patella and top of thigh. The procedure for the clinician to determine the 7 point body composition was as follows:

- Step 1: Wash hands with soap and water
- Step 2: Carefully locate anatomical landmarks while using verbal cues.
- Step 3: Firmly grasp the skinfold (in proper direction) with the pad on the thumb and index finger of the left hand.
- Step 4: Hold caliper in the right hand perpendicular to the skinfold and with the skinfold dial facing up for easy readability.
- Step 5: Place the caliper heads ¼ - ½ inch away from the fingers holding the skinfold. Open the caliper head and close the caliper on the skin fold.
- Step 6: The skinfold should contain two layers; one layer of skin and one layer of subcutaneous fat, but no muscle or fascia.
- Step 7: Release the handle of the calipers and read the needle to the nearest 0.1mm approximately two seconds after the pressure is released, repeat three times per site.
- Step 8: Document average result in recording log for each site assessment.

Maximal oxygen uptake (VO_2 max) and anaerobic threshold (AT)

Subjects performed a graded exercise test modified Tread Sport treadmill protocol that determined aerobic fitness and anaerobic threshold based on their maximal oxygen uptake via treadmill on both their testing visits to the laboratory. The subjects were instructed to breathe into a mouthpiece while the intensity of the exercise gradually increased to induce voluntary fatigue. Inspired and expired airflow as well as CO_2 and O_2 were analyzed by a Medgraphics Ultima metabolic analyzing system (Medgraphics, Minneapolis, MN). Ventilation (Ve), CO2 production (VCO_2), O_2 production (VO_2), and gas exchange ratio (VCO_2 / VO_2; R) was measured directly breath-by-breath. Heart rate (HR) was also measured and monitored as the test progresses.

Prior to the VO_2 max test, participants performed an exercise warm-up period of 5-10 minutes on a stationary bike with no resistance. While the warm up was being completed, participants were properly fitted with a Hans Rudolph mask and headgear for gas collection. Participants were instructed to use hand signals to notify researchers about the need to stop the test, all participants were shown how to get on/off the treadmill and education on a Borges rating of perceived exertion scale that was used during the test. Participants advanced through a series of stages increasing in mph and % grade incline via the Tread Sport treadmill protocol. Speeds and grade of the treadmill

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depended on the duration of the test. This continued until the subject became fatigued and decided to stop, or other symptoms such as, borge's scale, respiratory rate (RR), resting energy expenditure (RER) numbers proved otherwise and prohibited further exercise. During the VO_2 max test, the subject's heart rate was monitored either through a chest strap attached to a heart rate monitor. Participants were asked to rate their perceived exertion during the test at the beginning of each stage. After participants chose to stop the test they completed a walking cooldown for up to 5 minutes at a casual pace.

Results

A paired samples t-test, using SPSS v. 26, was conducted to determine significance ($p \leq 0.05$) on each of the four variables: VO_2 max, fasting blood glucose (GLU), anaerobic threshold (AT), and respiratory quotient (RQ). No significant differences were found when comparing groups on all variables (VO_2 $p= 0.923$,GLU $p= 0.099$,AT $p=0.641$, RQ $p=0.372$). See below in Table 1. Additionally, this is shown in the graphs below (Figures 1-4) when carbohydrate and placebo are compared for each test subject.

Table 1 Paired sample t-test using SPSS v. 26 of all four variables (VO GLU, AT, and RQ). X after each variable 2, is indicative of the carbohydrate supplement and O is indicative of the placebo supplement

Variable Pair	Degrees of Freedom (2-Tailed)	Sig.
VO2**X**-VO2**O**	10	0.923
GLU**X**-GLU**O**	10	0.099
AT**X**-AT**O**	10	0.641
RQ**X**-RQ**O**	10	0.372

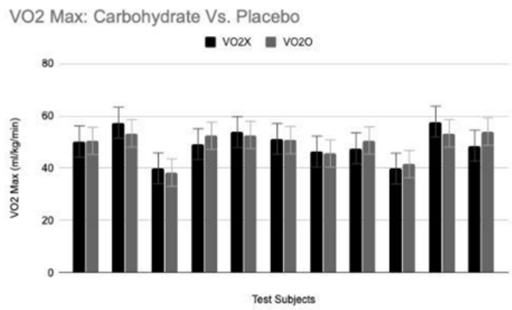

Figure 1 Carbohydrate versus placebo in VO_2 max test. X (Std Dev 5.94) indicates carbohydrate supplement and O (Std Dev 5.25) indicates placebo supplement.

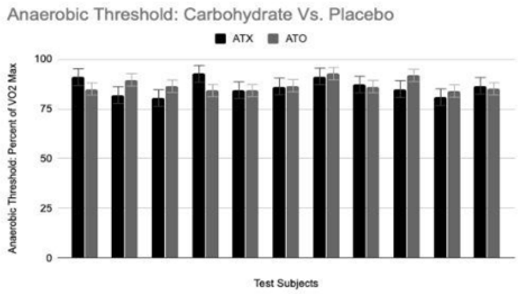

Figure 2 Carbohydrate versus placebo in anaerobic threshold as a percentage of VO_2 max. X (Std Dev 4.19) indicates carbohydrate supplement and O (Std Dev 3.10) indicates placebo supplement.

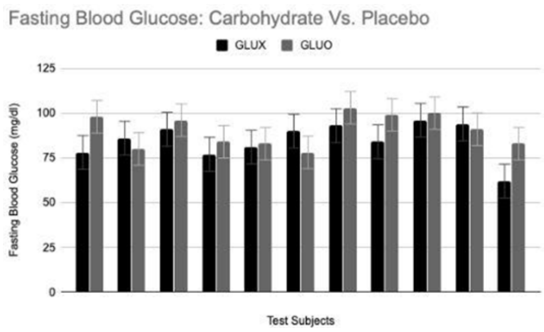

Figure 3 Carbohydrate versus placebo in fasting blood glucose. X (Std Dev 9.46) indicates carbohydrate supplement and O (Std Dev 9.09) indicates placebo supplement.

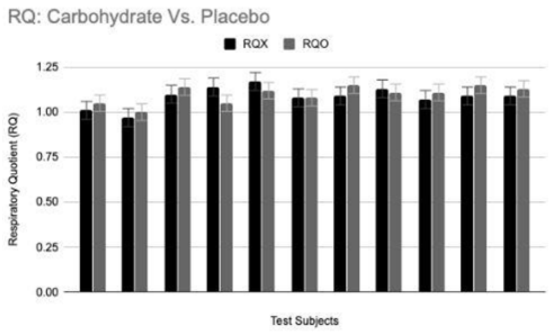

Figure 4 Carbohydrate versus placebo in respiratory quotient. X (Std Dev 0.05) indicates carbohydrate supplement and O (Std Dev 0.046) indicates placebo supplement.

Discussion

Acute CHO loading has no significant impact on performance variables as defined by AT, RQ, and VO_2 Data from this study suggests that the acute consumption of CHO max, made no difference in the test subjects' ability to reach peak performance. The present study's sample population offers insight into these results. All subjects within the present study were considered "active" according to ACSM standards, some of which participated in NCAA athletics. Glucose uptake into muscle cells requires GLUT-4 expression and GLUT-4 expression on cells is increased with exercise. The increased GLUT-4 expression on cells, particularly in an active population, can lead to increased insulin sensitivity.[11] Thus, since this study consisted of active individuals, they were able to lower their blood glucose levels back to homeostatic levels within the 12 hour time frame prior to their VO_2 max test. Since the subjects were already at homeostatic blood glucose levels, subjects could obtain MetF during their exercise test and performance was not impacted. This demonstrates that MetF plays a substantial role in the substrate used while performing a VO_2 max test, which could be a point of discussion regarding nutritional guidelines for active populations. Just as previous research found,[5] subjects were able to utilize CHO or fat with no effect on performance. Future research could focus on older athletes and the effect of acute consumption of CHO loading 12 hours prior to an exercise bout and its effect on performance. Similarly, populations who are not "active" by ACSM standards could have performance impacted by acute consumption of CHO loading 12 hours prior to an exercise bout and could be another avenue for further research. CHO loading 12 hours prior to performance may have different implications for 18-24 college aged active individuals than it would for others who are older or cannot obtain MetF and should be explored further.

Conclusion

Proper nutrition plays an important role in sports performance.[4] Based on the results of this study, the goal of obtaining increased sports performance seems to be largely dependent on the MetF of the individual. Participants were able obtain homeostasis of their blood glucose levels and utilize fat as an energy source during the study. While the results seem to suggest that CHO loading is not necessary to optimize performance, this area of study warrants further research as the understanding of substrate utilization gains better understanding within the sports performance world.

Acknowledgments

None.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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