ABSTRACT

THE EFFECTS OF A COCONUT BEVERAGE ON BLOOD GLUCOSE AND LACTATE CONCENTRATIONS

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Northern Illinois University, 2015
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Consumption of a carbohydrate (CHO) beverage during prolonged exercise has been shown to maintain plasma glucose levels. The purpose of this study was to examine the effects of a coconut beverage on blood glucose and lactate levels. Eleven endurance trained males participated in a repeated measures randomized double blind study. Each subject completed a VO$_{2\text{max}}$ followed by three 90 minute trials on treadmill run at 60-70% of their VO$_{2\text{max}}$, while consuming one of three beverages per trial (W=water, G=carbohydrate beverage, CB=coconut beverage). Every 15 minutes the subject drank 12 ounces of the beverage. A treadmill anaerobic test (TAT) was performed at completion of each 90 minute run. Blood glucose and lactate were measured at baseline, 15 min, 30 min, 45 min, 60 min, 75 min, 90 min, Post TAT, 5 min Post, and 10 min Post. There was a significant difference (p<0.05) found in blood glucose between W and the CHO supplements (G & CB). No significant difference was found between the G and CB (p>0.05). No significant difference (p>0.05) for lactate was found between any of the three beverages (W, G, CB) in terms of measured lactate concentration throughout the trial. Supplementing with CB can provide the same benefits as G in maintain blood glucose.

Keywords: coconut water; glucose; lactate; VO2 max test, treadmill anaerobic test
THE EFFECTS OF A COCONUT BEVERAGE ON BLOOD GLUCOSE AND LACTATE CONCENTRATIONS

BY

JOSH ALIS

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DEPARTMENT OF KINESIOLOGY AND PHYSICAL EDUCATION

Thesis Director:
Amanda Salacinski
ACKNOWLEDGEMENTS

To my Mom and Dad for always having faith in me and pushing me to be the best version of myself possible. I love the both of you and miss you Mom every day.
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<td>Comparisons of Means for Lactate for Three Beverages</td>
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INTRODUCTION

Athletic competitions and events cause athletes to perform activities which can be viewed as intense exercise. It is well known that intense exercise promotes depletion of energy stores such as blood glucose along with muscle and liver glycogen (Ali, Williams, Nicholas, & Foskett, 2007; Azevedo, Tietz, Two-Feathers, Paull, & Chapman, 2007; Brooks, Fahey, & Baldwin, 2005; McArdle, Katch & Katch, 2007). In today’s society, athletes are seeking out ways to enhance their athletic performance causing them to explore trends and fads that claim to augment their athletic activity. The competiveness of the sports world has driven athletes to utilize any substance that may provide them with an edge over their competition. To maintain performance athletes must be able to maintain blood glucose levels in order to supply the body with adequate amounts of adenosine triphosphate (ATP) while also monitoring lactate levels to prevent a decrease in performance.

Traditionally, sport drinks are used to increase performance in sports. Most drinks supply energy in forms of sugars or carbohydrates (CHO) such as glucose, fructose, and sucrose. CHO are commonly ingested in sport performance drinks for its ability to spare glucose and glycogen stores, which in turn, should delay the onset of fatigue (Brooks et al., 2005; Kenney, Wilmore, & Costill, 2012; McArdle et al., 2007). The consumption of CHO has been shown to have no effect on strength, power, or high-intensity exercise. However compared to no feeding, the consumption of a liquid either before or during exercise has been known to be beneficial for
endurance exercise. The intake of CHO during exercise allows one to sustain a higher intensity of exercise towards the end of an exercise bout (Brooks et al., 2005). Coleman (1994) concluded that both liquid and solid CHO feedings consumed during exercise are equally effective in prolonging endurance exercise as well as increasing blood glucose.

American College of Sport Medicine (ACSM) published a brochure by Simpson & Howard (2011) which educates consumers stating “carbohydrate consumption helps to sustain and improve exercise performance during high intensity exercise longer than one hour as well as lower intensity for longer periods in addition to helping replenish glucose/glycogen stores.”

Glycogen stores and CHO (as blood glucose) typically make up the primary fuel source for the body during aerobic exercise (Brooks et al., 2005; Kenney, et al., 2012; McArdle et al., 2007). After blood glucose is used, the body relies on muscle and liver glycogen stores respectively (Brooks et al., 2005; McArdle et al., 2007; Kenney, et al., 2012; Aulin, Sӧderlund, & Hultman, 2000). Glycogen depletion and low blood glucose (hypoglycemia) can limit performance and be a source of fatigue in exercise lasting 60-90 minutes (Kenney, et al., 2012; McArdle et al., 2007). Repeated or continuous exercise without replacing the body’s glycogen stores, the stored form of glucose, can lead to fatigue and decreased performance over time (Campbell, Prince, Braun, Applegate, Casazza, 2008; Reilly & Ekblom, 2005; Saltin, 1973).

Lactate also contributes to a decrease in exercise performance (McArdle, et al., 2007). Lactate, once thought to be an end product and metabolic waste from exercise, is now known to be a great energy source and fuel for the muscles of the body (Brooks et al., 2005). Lactate is an intermediate in CHO oxidation and is formed when the rate of pyruvate clearance is exceeded by
the rate of pyruvate appearance (McArdle et al., 2007). When lactate is formed in the blood or in
the muscle it must be moved to a source that can best utilize lactate as a substrate. There are few
different ways this can be done. Lactate is carried and shuttled to neighboring muscles by way of
the blood, so blood flow is very important when it comes to the ability of lactate exchange in the
body. If blood flow is increased it will increase lactate deliverance to neighboring muscles,
which are able to utilize lactate as an energy source, therefore, maintaining a more favorable
lactate concentration gradient (Gladden, 2000).

In today’s world more and more athletes are becoming educated on nutrition and the use
of exogenous products such as sport drinks. Many of these athletes are looking to make the
switch from some manufactured drink to something more natural and one such alternative is
coconut water (Coombes & Hamilton, 2000). Coconut water is naturally occurring and very rich
in potassium, contains sodium, and chloride which is not only vital to recovery but also promotes
becoming popular to the market is an all-natural coconut beverage aiming to eliminate chemical
additives, dyes and high fructose corn syrup found in leading fluid replacement beverages. It
also aims to replace and restore fluids and electrolytes lost through sweat and exercise as well as
reduce cramping and gastric distress which is also accompanied with conventional sport drinks.

The use of coconut water as a rehydrating agent has been used for years by people in
more humid climates such as the Middle East, South America, and Southeast Asia (Challem,
2009). The composition of coconut water can replenish electrolytes lost through sweat such as
potassium, sodium, magnesium and calcium leading to an affective rehydration drink (Brooks et
al., 2005, McArdle et al., 2007; Kalman et al., 2012; Yong, Ge, Fei Ng, & Ngin Tan. 2009). Ions are important because chloride is known as essential for fluid balance in the body; sodium and potassium are needed for muscles and nerves to work properly; and calcium helps muscles and blood vessels contract and expand (Brooks et al., 2005). Coconut beverage drinks also contain fewer additives and no high fructose corn syrup as does some other leading sport drinks on the market (Coco5.com, 2012). In terms of the effect of a coconut beverage on exercise in the US, very few peer reviewed research studies have been completed (Saat, Singh, Sirisinghe, & Nawawi., 2002).

Purpose

The purpose of this study was to examine the effects a coconut beverage has on blood glucose and lactate levels. Specially, to examine the effects of blood lactate and glucose during endurance exercise with water, a CHO-beverage, or a coconut beverage.
Hypothesis

The first hypothesis states that consumption of a coconut beverage (CB) will lead to an increase in blood glucose levels when compared to the water (W) and a leading CHO-beverage (G) during prolonged exercise.

The second hypothesis states that consumption of a CB will lead to the decrease of blood lactate levels when compared to W and G during prolonged exercise.

H1: There will be an increase in blood glucose concentrations between CB, G, and W groups.

H2: There will be a decrease in blood lactate concentrations between CB, G, and W groups.
METHODOLOGY

Subjects

Twenty-one physically active males aged 18-45 were recruited by posting flyers (Appendix A) within a 50 mile radius of Northern Illinois University (NIU) campus at local running clubs. Twelve of the twenty one subjects met all fitness and health criteria to complete participation. The twelve subjects were healthy, nonsmokers, of low cardiovascular risk based on ACSM guidelines (2014) and possessed no implanted electrical devices. All interested subjects were informed of the risks and benefits associated with the investigation and signed off on written consent (Appendix B) to participate in accordance with the Institution Review Board (IRB) at Northern Illinois University prior to the start of the study.

The criterion for participation included subjects running three times or more per week and the ability to perform exercise on a treadmill. Subjects’ health and exercise readiness were assessed using a medical history questionnaire (Appendix C). Only volunteers who were considered low cardiovascular risk according to the ACSM’s Guidelines for Exercise Testing and Prescription (Pescatello & American College of Sports Medicine, 2014) were considered to participate. Subjects must have been willing to take part in four running trials: one VO$_{2\text{max}}$ and three experimental trials. Those with more than one positive risk factor according to the ACSM guidelines (Appendix D) were excluded (Pescatello & American College of Sports Medicine,
Further, those with confirmed tree nut allergies or dietary restrictions which would prevent them from participating in the beverage protocol would also have been excluded from the study.

Procedures

Preliminary Screening

During the initial screening, subjects were asked to complete a medical history form and confirm that they were capable of performing the tasks required in this study. They were then asked to complete a 24 hour food recall (Appendix E) which was analyzed using NutritionCalcPlus 3 software (2008, McGraw Hill Education, Columbus, OH). Participants were asked to abstain from intense exercise 24 hours prior to their exercise sessions, as well as, refrain from eating two hours before the trial. Additionally, they had been instructed to wear athletic apparel, including adequate running shoes. Anthropometric measurements (height, weight, percent body fat, and water content) were taken in light clothes and bare feet using an InBody520 body composition analyzer (Cerritos, CA, 2011), along with a SECA 220 stadiometer (Germany) to measure height. The subject’s had their height measured during their first visit and this value was used in following visits. The subjects were asked to remain standing for at least 15 minutes prior to InBody measurements to reduce fluctuations in impedance values. To assure the subject remained standing for the proper time, the researchers asked the subject to complete the demographic information on the data collection sheet (Appendix F) while standing upright.
The subject was asked to complete a maximal oxygen uptake (VO$_{2\text{max}}$) test to establish a baseline for the subject to be used in later trials when they were asked to run at 60-70% their VO$_{2\text{max}}$. The VO$_{2\text{max}}$ was determined on a motor powered DESMO Woodway Treadmill (Waukesha, WI), which allowed the researchers to manipulate the speed and incline. The subjects were connected to a Parvo Medics Trueone 2400 metabolic cart (Sandy, UT) during the VO$_{2\text{max}}$ trial. The subjects were also fitted with a Polar FT2 Heart rate chest band along with a T31 coded watch monitor to observe rise and falls in HR during exercise. The protocol used was based upon a modified Balke Test. The subjects began with a three minute time period in which the investigators increased or decreased the speed of the treadmill which was at a 0% grade. The purpose of this 3 minute time period was to get the subjects’ RER between 0.85-0.90. Following this period, the treadmill speed was held at the determined speed found in the first 3 minutes.

To get the subject to their VO2 max the grade of the treadmill increased every 2 minutes. The grade increased by 2% after the first 2 minutes and then increased 3% every 2 minutes after (2%, 5%, 8%, 11%, and 14%). If the subject reached 14% incline they continued to run at that setting until volitional fatigue. VO$_2$ was obtained every 30 seconds throughout the test and the maximal value was determined by averaging the values obtained during the final two minutes of exercise. The criteria for VO$_{2\text{max}}$ attainment included achieving at least two of the following measures: 1) Reaching a plateau in VO$_2$ (<2.1 ml/kg/min increase) in the final two stages despite an increasing workload; 2) achieving an RER $\geq$ 1.10; 3) reaching a HR within five bpm of predicted maximum heart rate (220-age) or 4) blood lactate concentration of 8-9 mmol. VO$_{2\text{max}}$ was recorded as the highest 15 second average prior to volitional exhaustion and was
expressed in relative terms (ml/kg/min). The subjects had blood samples collected prior to and one minute after performing the VO\textsubscript{2max} protocol. Finger sticks were made using a single use disposable Accu-Check, Safe-T-Pro lancelet. Blood glucose and lactate were analyzed using the YSI 2300 from Yellow Springs Instrument Company (Yellow Springs, OH).

**Experimental Sessions**

On all testing days, subjects were asked to report in comfortable and appropriate running attire and shoes, and follow established protocol regarding abstaining from exercise 24 hours and food two hours prior to their exercise session. Anthropometric data was collected in light exercise clothing and bare feet. This included an InBody520 (Cerritos, CA) body composition analyzer for weight and percent composition data. Subjects also submitted their 24 hour food recall with them to their report time. The diet was analyzed and all subjects’ were asked to keep diet and exercise plans consistent for the duration of the study. The nutrition data was analyzed using NutritionCalcPlus 3 software (2008, McGraw Hill education, Columbus, OH).

In each trial, subjects were randomly assigned to consume either local filtered tap water (W), a coconut beverage (CB), or a diluted CHO-beverage (G). For the current study the CB used was COCO5, a coconut water company based out of Chicago, IL. All beverages were served in bottles in which one was unable to see the beverage. The order of each trial and beverage was double blind. The beverages were mixed and distributed by a third party who did not disclose information to the subject’s or the researchers. The beverages were also served cool but not ice cold. The CB and G were closely matched in CHO and calorie content: 12 oz CB
contained 60 calories and 12 g CHO while the diluted G solution was composed of 8 oz G and 4 oz water, which contained roughly 53 calories and 14 g CHO.

Subjects completed a 90 minute walk/run at 60-70% their VO$_{2\text{max}}$ while randomly being connected to the Trueone 2400 metabolic cart (Parvo Medics; Sandy, UT). The subjects were attached to the metabolic cart at least twice during the 90 minutes to assure they were in the desired range. Researchers adjusted the speed of the treadmill as necessary to maintain the 60-70% range for VO$_{2\text{max}}$ (incline remained at 0 for the duration of the trial). Researchers monitored compliance and recorded any changes in speed (Appendix F). Trials took place in normal environmental conditions. At 15 minute intervals, subjects were asked to step off the moving treadmill belt (“straddling” the treadmill). The subjects were given 12 ounces of one of the three beverages (W, CB, G dilution) and asked to drink all of it within 60 seconds and continue running. The subjects also had blood samples collected at baseline, prior to stepping on the treadmill, and 15 minute intervals via a standard protocol for blood glucose and lactate. Blood glucose and lactate was analyzed using the YSI 2300 from Yellow Springs Instrument Company (Yellow Springs, OH). A total of 32 finger sticks were made using a single use disposable Accu-Check, Safe-T-Pro lancelet from Fisher Scientific (Indianapolis, IN. #13-678-45). Heart rate (HR) and rating of perceived exertion (RPE), using the OMNI scale, were also recorded in 15 minute increments, and continued at the 30, 45, 60, and 75 minute mark. At the 90 minute mark, the subject straddled the treadmill belt as variables lactate, glucose, HR and RPE were collected. Subjects did not drink any beverage at this time. Immediately after measurements were completed, the researcher raised the treadmill to 20% incline and set the
speed at 8 mph for the treadmill anaerobic test (TAT). The subject was asked to run on the treadmill for as long as they could, and time until volitional fatigue was recorded. Immediately following the TAT, 5 and 10 minutes of rest after the TAT, blood glucose and lactate, HR, and RPE were collected. After recovery, subjects were not given additional food and beverage but were encouraged to go eat a snack and be dismissed. They were not debriefed or given results until all three experimental trials were complete for all eleven subjects. The exact protocols were repeated for another two trials with the remaining beverages.

**Statistical Analysis**

A repeated measures analysis of variance (ANOVA) was conducted between subjects on the three variables (W, CB, G beverage) to see if there is a difference between blood glucose and lactate concentrations over time. Statistical analysis using SPSS software (version 22.0, 2013, Armonk, NY) will be used. The alpha level will be set at 0.05, power is established at ≥0.80, and it is assumed that if there is an effect, the effect size (partial eta²) will be anticipated to be moderate in size, minimally. A G*Power analysis using alpha=0.05, power=0.80, and a moderate effect indicated that for the current study a sample size of at least 15 would have to be attained in order to meet a power of >0.80. Statistically significant mean differences were looked at by polynomial contrasts with emphasis placed on the highest point in time. Descriptive data will be presented as the mean ± standard deviation (SD).

Variables at each time point were measured for normative distribution. Kurtosis and skewness were observed (between +2.00 and -2.00), as well as the Shapiro-Wilk and Kolmogorov-Smirnov tests (p>0.05). All glucose time variables were found to be normally
distributed according to the above criteria. Not all lactate time points were found to be normally distributed (15 min, 30 min, 45 min, and 75 min). These four lactate time points had elevated kurtosis beyond the parameters of -2 to +2. All other time points were found to be significantly distributed according to the criteria set in place above.

Glucose and lactate at each time point was measured for outliers. Kurtosis and skewness were observed, as well as Shapiro-Wilk (p>0.05), and standardized residual (ZRE) (<±3.0) were used to determine outliers. One outlier for glucose only was found and no outliers for lactate were found.
RESULTS

Twenty-one subjects were recruited to take part in the current study, of the twenty-one recruits, seventeen completed preliminary testing. Of the seventeen subjects who took part in preliminary testing, one subject dropped out after his second run citing knee soreness while another subject injured his foot outside of the study and could no longer participate. A third subject had other obligations on his schedule which kept him from continuing the study. There were two subjects who did not meet the VO$_2$ criteria and therefore did not qualify for the study. Another subject was removed from the final analysis for glucose only due to his physiological responses. This subject met all criteria for testing but his glucose values fell to dangerous levels and never rose up to normal values. These readings led researchers to believe there was a possible underlying health issue or hormonal response difference which he was made aware of at the conclusion of testing. Those who either dropped out or did not meet the criteria were not included in any statistical analyses. Of the seventeen subjects who completed preliminary testing, only twelve of the subjects who met all criteria took part in the current study and eleven were used for the final analysis for glucose while all twelve were used for lactate. Descriptive statistics for all subjects were calculated and are presented in Table 1.0.
Table 1.0. Descriptive Statistics for Subjects

<table>
<thead>
<tr>
<th>Variables (n=12)</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>24.92</td>
<td>6.76</td>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>178.17</td>
<td>5.39</td>
<td>166</td>
<td>184</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>76.50</td>
<td>7.49</td>
<td>67.37</td>
<td>90.23</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.08</td>
<td>2.35</td>
<td>19.95</td>
<td>28.16</td>
</tr>
<tr>
<td>VO₂max (ml<em>kg⁻¹</em>min⁻¹)</td>
<td>56.13</td>
<td>5.33</td>
<td>48.733</td>
<td>65.35</td>
</tr>
</tbody>
</table>

Blood glucose along with blood lactate was measured across time. The means and standard deviations (mean±standard deviation) of blood glucose and blood lactate for the 90 minute run can be found in Table 2.1 and 2.2 respectively. The means and standard deviations for the post-test measurements of glucose and lactate can be found in Table 3.1 and 3.2, respectively.

Table 2.1 Blood Glucose Comparisons across 90 minutes (n=11)

<table>
<thead>
<tr>
<th>Drink</th>
<th>Baseline</th>
<th>15 min</th>
<th>30 min</th>
<th>45 min</th>
<th>60 min</th>
<th>75 min</th>
<th>90 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>78.8±12.07</td>
<td>64.0±9.4</td>
<td>71.36±8.4</td>
<td>73.5±9.7</td>
<td>70.4±9.7</td>
<td>68.6±9.2</td>
<td>67.6±7.5</td>
</tr>
<tr>
<td>G</td>
<td>78.6±11.5</td>
<td>63.1±7.6</td>
<td>76.3±9.7</td>
<td>87.1±9.5</td>
<td>82.5±8.0</td>
<td>78.3±6.4</td>
<td>76.9±7.9</td>
</tr>
<tr>
<td>CB</td>
<td>79.89±13.9</td>
<td>64.1±11.7</td>
<td>76.8±12.9</td>
<td>85.6±11.9</td>
<td>80.8±12.1</td>
<td>74.4±11.8</td>
<td>77.4±11.3</td>
</tr>
</tbody>
</table>

W=Water  
G=CHO-beverage  
CB=Coconut beverage
Table 2.2 Blood Lactate Comparisons across 90 minutes (n=12)

<table>
<thead>
<tr>
<th>Drink</th>
<th>Baseline</th>
<th>15 min</th>
<th>30 min</th>
<th>45 min</th>
<th>60 min</th>
<th>75 min</th>
<th>90 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>1.25±0.25</td>
<td>1.56±0.74</td>
<td>1.42±0.60</td>
<td>1.27±0.62</td>
<td>1.14±0.56</td>
<td>1.28±0.54</td>
<td>1.31±0.51</td>
</tr>
<tr>
<td>G</td>
<td>1.03±0.24</td>
<td>1.43±0.70</td>
<td>1.25±0.44</td>
<td>1.27±0.38</td>
<td>1.27±0.38</td>
<td>1.27±0.24</td>
<td>1.28±0.35</td>
</tr>
<tr>
<td>CB</td>
<td>0.99±0.35</td>
<td>1.67±1.36</td>
<td>1.55±0.89</td>
<td>1.70±1.15</td>
<td>1.45±0.59</td>
<td>1.42±0.60</td>
<td>1.42±0.49</td>
</tr>
</tbody>
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W=Water  
G=CHO-beverage  
CB=Coconut beverage

Table 3.1 Blood Glucose Comparisons across Post-Measurement Tests (n=11)

<table>
<thead>
<tr>
<th>Drink</th>
<th>Post TAT</th>
<th>5 min Post</th>
<th>10 min Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>73.5±10.7</td>
<td>81.6±10.8</td>
<td>77.7±12.1</td>
</tr>
<tr>
<td>G</td>
<td>78.1±9.5</td>
<td>94.3±18.6</td>
<td>90.8±17.7</td>
</tr>
<tr>
<td>CB</td>
<td>78.6±14.5</td>
<td>95.5±17.9</td>
<td>92.8±21.3</td>
</tr>
</tbody>
</table>

W=Water  
G=CHO-beverage  
CB=Coconut beverage

Table 3.2 Blood Lactate Comparisons across Post-Measurement Tests (n=12)

<table>
<thead>
<tr>
<th>Drink</th>
<th>Post TAT</th>
<th>5 min Post</th>
<th>10 min Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>7.4±2.8</td>
<td>8.8±3.4</td>
<td>7.4±3.7</td>
</tr>
<tr>
<td>G</td>
<td>7.7±2.4</td>
<td>9.1±3.1</td>
<td>8.1±3.0</td>
</tr>
<tr>
<td>CB</td>
<td>7.1±2.3</td>
<td>8.5±2.7</td>
<td>7.5±2.8</td>
</tr>
</tbody>
</table>

W=Water  
G=CHO-beverage  
CB=Coconut beverage

All tests across time failed to meet assumption of sphericity (p=<0.05) and in turn had a correction factor applied to each test, which is known to lower statistical power due to its corrective nature. Due to the failure of meeting assumption of sphreicity, the Greenhouse-Geisser correction was used. A repeated measures analysis of variance (ANOVA) was used to measure any statistically significant changes across time for each of the beverages. For glucose in W, a
statistical significance (F=13.645, p<0.001) in the measure over time and a power of 1.000 were found. What power shows is that if there were to be an effect then that effect would be observed 100% of the time. There was a measured effect size of 0.577 which tells that for the within W effect, 57.7% of the variance in the glucose measure is accounted for due to the drink.

A polynomial contrasts was used to test where the differences lied with fixed attention being on the highest order in time. There was a significant difference between the 60 minute and 75 minute mark (F=30.33, p<0.001) with a measured effect size of 0.752 and an observed power of 0.998. The effect size and power decreased due to the movement in time which consumes power. Figure 1.0 represents how glucose tracked over time for W. Subjects experienced a drop at the 15 minute collection then increased by the 30 minute collection. After minute 45 they experienced a gradual decrease in blood glucose until they completed the TAT in which glucose began to increase.

![Figure 1.0 Change in Average Glucose over time for W.](image-url)
A repeated measures ANOVA was used to measure statistical significant changes across time for each of the beverages. Lactate for W was found to be statistically significant (F=41.586, p<0.001) in measures over time (power=1.000) with a measured effect size of 0.791. Polynomial contrasts were used to test where significant difference were found with fixed attention on the highest point in time. The highest order of significant difference found was between 5 minute post and 10 minute post measurements (F=49.360, p<0.001). A measure of effect size of 0.8181 along with an observed power of 1.000 was found at this time point. Figure 2.0 represents how lactate tracked over time for water. A steady-state in blood lactate was consistent for all subjects in all trials until the TAT in which all lactate levels significantly increased (F=35.1, p<0.001). Lactate levels can be seen to peak at the 5 minute post measurement before declining in the 10 minute post.

Figure 2.0 Change in Average Lactate over time for W.
Glucose for G was looked at over time and was found to be significant ($F=13.125$, $p<0.001$) with a measured effect size of 0.568 and an observed power of 0.996. A repeated measures ANOVA and polynomial contrasts were used to test significance between measurements with fixed attention on the highest point in time. The time between TAT and the 5 minute post measurements were found to be the highest significant order in time ($F=12.56$, $p=0.005$) with a measured effect size of 0.557 as well as an observed power of 0.890. Figure 3.0 represents how glucose measured over time for G. As with W, glucose levels decreased by the first 15 minute measurement before again increasing up until minute 45, after which glucose began to decline before increasing again between the post TAT and 5 minute post measurement.

Figure 3.0 Change in Average Glucose over time for G.
Lactate for G was also looked at over time and was found to be significant ($F=72.693$, $p<0.001$). The measured effect size was 0.869 while the observed power was 1.000. A repeated measures ANOVA and polynomial contrasts were used to test significance. The time between the 5 minute post and the 10 minute post measurements were found to be the highest significant order in time ($F=81.150$, $p<0.001$) with a measured effect size of 0.881 as well as an observed power of 1.000. Subjects maintained a steady lactate level through the 90 minutes.

![Figure 4.0 Change in Average Lactate over time for G.](image.png)

Glucose for CB was also looked at over time and was found to be significant ($F=12.734$, $p<0.001$). A measured effect size of 0.56 and an observed power of 0.998 were calculated from the Greenhouse-Geisser correction factor. A repeated measures ANOVA and Polynomial
contrasts were used to test significance between measurements with fixed attention on the highest point in time. The time between the TAT and the 5 minute post measurements were found to be the highest significant order in time \((F=14.95, p=0.003)\) with a measured effect size of 0.599 as well as an observed power of 0.935. Glucose in Figure 5.0 follows a similar trend to that of Figure 3.0.

![Figure 5.0 Change in Average Glucose over time for CB.](image)

Lactate for CB was looked at over time and again was found to be significant \((F=54.796, p<0.001)\). A measured effect size of 0.833 was found along with an observed power of 1.000. The highest order in time found to be significant was the difference between the 5 and 10 minute post measurements \((F=64.463, p<0.001)\) with a measured effect size of 0.854 as well as an observed power of 1.000. Figure 6.0 shows how lactate means were marked throughout the tests.
A one-way ANOVA was used to compare all three drinks to each other at each time point for both glucose and lactate. The Levene’s test was used to test the assumption for equality of population variances for each time point. The results for variance can be found in Table 4.0. All time points meet the assumption for equality of population variance (p>0.05) except for the 45 minute mark for lactate (p=0.007). Meeting this assumption is not only important for power, but also for the omnibus F test in that it is less likely to succumb to elevated type I error. Type I error represents a false positive in the testing.
Table 4.0 Assumption for Equality of Population Variances Across Time

<table>
<thead>
<tr>
<th>Time</th>
<th>Glucose</th>
<th></th>
<th>Lactate</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
<td>F</td>
<td>Sig.</td>
</tr>
<tr>
<td>Base</td>
<td>.531</td>
<td>.594</td>
<td>.447</td>
<td>.644</td>
</tr>
<tr>
<td>15 min</td>
<td>.887</td>
<td>.422</td>
<td>1.502</td>
<td>.237</td>
</tr>
<tr>
<td>30 min</td>
<td>.704</td>
<td>.503</td>
<td>.931</td>
<td>.404</td>
</tr>
<tr>
<td>45 min</td>
<td>.209</td>
<td>.813</td>
<td>5.085</td>
<td>.012</td>
</tr>
<tr>
<td>60 min</td>
<td>.638</td>
<td>.535</td>
<td>1.289</td>
<td>.289</td>
</tr>
<tr>
<td>75 min</td>
<td>1.682</td>
<td>.203</td>
<td>2.312</td>
<td>.115</td>
</tr>
<tr>
<td>90 min</td>
<td>2.176</td>
<td>.131</td>
<td>1.826</td>
<td>.177</td>
</tr>
<tr>
<td>PostTAT</td>
<td>1.365</td>
<td>.271</td>
<td>.153</td>
<td>.859</td>
</tr>
<tr>
<td>5 min</td>
<td>1.397</td>
<td>.263</td>
<td>.261</td>
<td>.772</td>
</tr>
<tr>
<td>10 min</td>
<td>1.093</td>
<td>.348</td>
<td>.388</td>
<td>.681</td>
</tr>
</tbody>
</table>

† P-VALUE <0.05, not evenly distributed

Glucose values were compared between drinks over each time and can be seen in Table 5.0. Table 5.0 displays the F-value, P-value, the Partial Eta, and the Observed Power. At minute 45 there is a significant difference between drinks (p=0.005). The drink comparisons can be found in Table 6.0. Table 6.0 shows differences between each drink as it measures glucose levels. Minutes 45, 60, 75, and 90 were the only ones to have significance from their omnibus F test, they are the only points in time displayed in Table 6.0.
Table 5.0 Glucose ANOVA F-Statistics for Three Beverages Across Time

<table>
<thead>
<tr>
<th>Time</th>
<th>F</th>
<th>P-value</th>
<th>Partial eta squared</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>0.035</td>
<td>.965*</td>
<td>0.002</td>
<td>0.055</td>
</tr>
<tr>
<td>15 min</td>
<td>0.030</td>
<td>.971*</td>
<td>0.002</td>
<td>0.054</td>
</tr>
<tr>
<td>30 min</td>
<td>0.909</td>
<td>.414*</td>
<td>0.057</td>
<td>0.192</td>
</tr>
<tr>
<td>45 min</td>
<td>5.114</td>
<td>.012†</td>
<td>0.254</td>
<td>0.787</td>
</tr>
<tr>
<td>60 min</td>
<td>4.706</td>
<td>.017†</td>
<td>0.239</td>
<td>0.745</td>
</tr>
<tr>
<td>75 min</td>
<td>3.967</td>
<td>.030†</td>
<td>0.209</td>
<td>0.667</td>
</tr>
<tr>
<td>90 min</td>
<td>4.056</td>
<td>.028†</td>
<td>0.213</td>
<td>0.667</td>
</tr>
<tr>
<td>Post tat</td>
<td>0.636</td>
<td>.537*</td>
<td>0.041</td>
<td>0.146</td>
</tr>
<tr>
<td>5 min post</td>
<td>2.493</td>
<td>.100*</td>
<td>0.142</td>
<td>0.461</td>
</tr>
<tr>
<td>10 min post</td>
<td>2.414</td>
<td>.107*</td>
<td>0.139</td>
<td>0.449</td>
</tr>
</tbody>
</table>

*No significant difference
† Significant difference

W=Water
G=CHO-beverage
CB=Coconut beverage

Table 6.0 Glucose Comparison of Three Beverages at Minutes 45-90

<table>
<thead>
<tr>
<th>Time</th>
<th>Drink (1)</th>
<th>Drink (2)</th>
<th>Mean Difference</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 min</td>
<td>W</td>
<td>G</td>
<td>-13.6227</td>
<td>.020†</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CB</td>
<td>-12.0455</td>
<td>.045†</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>CB</td>
<td>1.5773</td>
<td>1.000</td>
</tr>
<tr>
<td>60 min</td>
<td>W</td>
<td>G</td>
<td>-12.2045</td>
<td>.024†</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CB</td>
<td>-10.4409</td>
<td>.064</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>CB</td>
<td>1.7636</td>
<td>1.000</td>
</tr>
<tr>
<td>75 min</td>
<td>W</td>
<td>G</td>
<td>-9.7136</td>
<td>.064</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CB</td>
<td>-9.7773</td>
<td>.061</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>CB</td>
<td>-0.0636</td>
<td>1.000</td>
</tr>
<tr>
<td>90 min</td>
<td>W</td>
<td>G</td>
<td>-9.2682</td>
<td>.069</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CB</td>
<td>-9.7773</td>
<td>.051†</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>CB</td>
<td>-0.5091</td>
<td>1.000</td>
</tr>
</tbody>
</table>

†Significant difference between drinks

W=Water
G=CHO-beverage
CB=Coconut beverage

There was a significant difference found between W and G (p=0.020) as well as between W and CB (p=0.045) at minute 45. There was however, no significant difference between G and
CB (p=1.000). Minute 60 was statistically significant as well (p=0.017) between the three drinks (W, G, and CB). When looking at the difference between drinks at the 60 minute time point, there was a significant difference between W and G (p=0.024), but no significant difference between W and CB (p=0.064) and again no significant difference between G and CB (p=1.000). There was a significant difference found at minute 75 (p=0.030), however no significant difference was found between drinks W and G (p=0.064), W and CB (p=0.061), or G and CB (p=1.000) at this timepoint. However, if one were to look at the mean differences displayed in Table 6.0 comparing the three beverages to each other, they would see that the largest mean difference belongs to the comparison between W and CB (9.7773) followed closely by the difference between W and G (9.7136). The comparison of G and CB provided a very low mean difference (0.0636), indicating the beverages were similar.

The final significant time point found for glucose was at minute 90 (p=0.028). At minute 90 the beverages which were the closest to being statistically significant was the comparison of W and CB (p=0.051). With more subjects the measurement between W and CB at 90 minutes may have been found to be statistically significant. The differences between W and G (p=0.069) and G and CB (p=1.000) at 90 minutes were found to be not significantly different. Figure 7 shows glucose over time for each beverage.
Table 7.0 represents the comparison of lactate values between W, G, and CB. There were no significant differences (p>0.05) found for lactate when comparing the three drinks at each time period. Figure 8.0 represents lactate over time for beverages W, G, and CB.
Table 7.0 Lactate ANOVA F-Statistics for Three Beverages (W, G, CB) Across Time

<table>
<thead>
<tr>
<th>Time</th>
<th>F</th>
<th>P-value</th>
<th>Partial eta squared</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>3.018</td>
<td>.063</td>
<td>.155</td>
<td>.546</td>
</tr>
<tr>
<td>15 min</td>
<td>.177</td>
<td>.838</td>
<td>.011</td>
<td>.075</td>
</tr>
<tr>
<td>30 min</td>
<td>.630</td>
<td>.539</td>
<td>.037</td>
<td>.146</td>
</tr>
<tr>
<td>45 min</td>
<td>1.208</td>
<td>.312</td>
<td>.068</td>
<td>.245</td>
</tr>
<tr>
<td>60 min</td>
<td>1.067</td>
<td>.356</td>
<td>.061</td>
<td>.221</td>
</tr>
<tr>
<td>75 min</td>
<td>.437</td>
<td>.649</td>
<td>.026</td>
<td>.115</td>
</tr>
<tr>
<td>90 min</td>
<td>.267</td>
<td>.767</td>
<td>.016</td>
<td>.089</td>
</tr>
<tr>
<td>Post tat</td>
<td>.147</td>
<td>.864</td>
<td>.009</td>
<td>.071</td>
</tr>
<tr>
<td>5 min post</td>
<td>.099</td>
<td>.906</td>
<td>.006</td>
<td>.064</td>
</tr>
<tr>
<td>10 min post</td>
<td>.158</td>
<td>.855</td>
<td>.009</td>
<td>.072</td>
</tr>
</tbody>
</table>

* No significant difference between drinks
W=Water
G=CHO-beverage
CB=Coconut beverage

Figure 8.0 Comparisons of Means for Lactate for Three Beverages
DISCUSSION

The purpose of this study was to examine the effects a coconut beverage has on blood glucose and lactate levels. The effects the three drinks (W, G, CB) had on blood glucose and lactate were compared during a 90 minute submaximal treadmill run, followed by a TAT to volitional fatigue. Subjects were given and asked to consume 120 ounces of a given beverage for each trial. The findings of the current study suggest that supplementation with a coconut beverage may be just as effective in maintaining blood glucose as supplementing with a widely researched sport drink. This study is also in agreement with previous literature that supplementation of a CHO-beverage during a prolonged aerobic exercise will maintain blood glucose better than consuming water (Ali et al., 2007; Bosch, 2007; Brooks et al., 2005; Cermak & van Loon, 2013; Coleman, 1994; Jeukendrup, 2004; Jeukendrup, 2007; McArdle et al., 2007; Stellingwerff, Boon, Gijsen, Stegan, Kuipers, & van Loon, 2007; Wilmore & Costill, 2004).

For each drink examined in the current study, blood glucose was examined across the entire 90 minutes. Blood glucose measurements for each drink followed the same pattern. As exercise began, blood glucose decreased initially at the 15 minute measurement before increasing and peaking at 45 minutes for each drink. After the 45 minutes, glucose began to decline as exercise continued (Figure 7.0).
As the body performs work, glucose is taken up from the blood to be utilized by the working tissues as fuel (McArdle et al., 2007). As blood glucose is utilized for energy, glycogen, which is the stored form of glucose, is broken down to maintain blood glucose. Therefore, during exercise the muscle will use the limited stores of glycogen located in the muscle before utilizing glucose from the plasma and glycogen stored in the liver. Exercise causes an increased uptake of blood glucose to allow for cellular ATP homeostasis. Increased uptake lowers the glucose in the blood which causes coordinated physiological responses to maintain blood glucose homeostasis (Brooks et al., 2005).

During early moderate exercise it has been found that plasma glucose provides around 1/3 of CHO oxidation while muscle glycogen accounts for the other 2/3. However, as exercise continues a shift can be seen as plasma glycogen increases and muscle glycogen decreases (McArdle et al., 2007). A large contributor to fatigue when exercise is prolonged, as it was in the current study, is a decline in muscle glycogen caused by the original decline in plasma glucose (Lamb & Murray, 1999). The decrease in muscle glycogen causes the body to begin breaking down the limited stores of glycogen in the liver and kidney. As the glycogen stores become depleted the body loses the ability to keep an elevated blood glucose level. As blood glucose drops, so does the availability of usable energy to not only the working muscles but also the central nervous system causing the fatigue and the cessation of activity.

Research has indicated the importance of taking in a source of CHO during long endurance exercise at a submaximal intensity (Brooks et al., 2005; Campbell et al., 2008;
Cermak, 2013; Coleman, 1994; Currell & Jeukendrup, 2008; Jeukendrup, 2007; Kenney, Wilmore, & Costill, 2012). Jeukendrup (2007) suggests taking a CHO supplementation every 15-20 minutes during prolonged bouts of exercise can be beneficial. The amount an athlete should take in depends on the event and the intensity. Studies have indicated that the body is able to use CHO at a rate of 1 g/min when glucose alone is consumed and up to 1.5 g/min when multiple sources of CHO are taken in. These results may lead to speculation that a range of 60-90 g/hr may lead to optimal performance (Smith et al., 2013; Bosch, Dennis, & Noakes, 1994; Jentjens, Moseley, Waring, Harding, & Jeukendrup, 2004; Jentjens, Venables, & Jeukendrup, 2004; Jeukendrup, Moseley, Mainwaring, Samuels, Perry, & Mann, 2006; Jeukendrup, Wagenmakers, Stegan, Gijsen, Brouns, & Saris, 1999; Wagenmakers, Brouns, Saris, & Halliday, 1993). The greater the intensity the more reliant the working muscle becomes on CHO as a fuel source (McArdle et al., 2007; Saltin, 1973; Wilmore & Costill, 2004; Wong & Chen, 2011). Jeukendrup (2007) also suggests a highly concentrated solution can slow fluid delivery suggesting the given supplementation drink should be no more than 7% CHO (16.3 g/ 8 oz). It is suggested that ingesting a combination of CHO such as glucose, sucrose, maltose, fructose, and galactose will increase the rate of energy delivery. In the current study the subjects were taking in CHO drinks with solutions of less than 7% (G: 14 g/12 oz.; CB: 12g/12 oz.). The CHO content of the drinks would be below that of the suggested range of 60-90 g/hr. Both drinks were also made with multiple CHO sources as suggested previously.
In the current study, supplementation with CB did provide similar results as a leading CHO-beverage (G). Both drinks containing CHO were found to be better than water (p<0.05) in providing the body with glucose. However, neither drink (G or CB) was found to significantly provide a greater amount of glucose than the other (p=1.00). Coconut water, which is the leading ingredient in CB, is a more natural form of CHO supplementation then the manufactured sport drinks. Therefore, CB is able to provide the body with more electrolytes then that of a leading sport drink as can be seen in Table 8.0

Many of the familiar sport drinks contain fructose, maltodextrin, artificial flavors, sweeteners and added electrolytes (i.e. sodium & potassium) (Kalman et al., 2012). Coconut beverages, such as the one used in the current study (CB), are made of more all natural ingredients such as pure cane sugar, natural sea salt, natural rebiana, and natural flavor and juices. Coconut beverages do not contain any harmful chemicals, preservatives or dyes (COCO5.com, 2012). Coconut water, a leading ingredient in coconut beverages, is reported to have antioxidant properties aiding in neutralizing reactive oxygen species resulting from long duration exercise. Coconut water is also abundant in inorganic ions and vitamins to help the body function properly (Kalman et al., 2012; Yong, et al., 2009). Providing the body with electrolytes, which are lost through sweat, maintains the muscles ability to function properly as well as maintaining the neural system (Brooks et al., 2005; Challem, 2009; Coombes & Hamilton, 2000; Kalmen et al., 2012).
At 45 minutes, there is a significant difference found in mean blood glucose between beverages W and G (p=0.020) and beverages W and CB (p=0.045). There was no significant difference in blood glucose between beverages G and CB (p=1.000). At minute 60 there remained a significant difference between W and G (p=0.024), but no significant difference between W and CB (p=0.064) or G and CB (p=1.000). While the differences between W & G (p=0.069) as well as G and CB (p=1.000) were not statistically different at 90 minutes, W and CB came very close to being significantly different (p=0.051) in blood glucose.

Similar to previous research there was a significant difference in blood glucose between the W and both CHO beverages (p<0.05)(Azevedo et al., 2007; Baechle & Earle, 2008; Brooks et al., 2005; Cermak, & van Loon, 2013; Currell & Jeukendrup, 2007; McArdle et al., 2007;)

Table 8.0 Inorganic Ions and Vitamins Found in Coconut Water

<table>
<thead>
<tr>
<th>Inorganic Ions</th>
<th>Vitamins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Vitamin C</td>
</tr>
<tr>
<td>Iron</td>
<td>Thiamin (B1)</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Riboflavin (B2)</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Niacin (B3)</td>
</tr>
<tr>
<td>Potassium</td>
<td>Pantothenic acid (B5)</td>
</tr>
<tr>
<td>Sodium</td>
<td>Pyridoxine (B6)</td>
</tr>
<tr>
<td>Zinc</td>
<td>Folate</td>
</tr>
<tr>
<td>Copper</td>
<td>Folic acid</td>
</tr>
<tr>
<td>Manganese</td>
<td>Biotin</td>
</tr>
<tr>
<td>Selenium</td>
<td>Niacin</td>
</tr>
<tr>
<td>Chlorine</td>
<td>-</td>
</tr>
<tr>
<td>Sulfur</td>
<td>-</td>
</tr>
<tr>
<td>Aluminum</td>
<td>-</td>
</tr>
<tr>
<td>Boron</td>
<td>-</td>
</tr>
</tbody>
</table>
The significant differences between W and the two CHO beverages (G and CB) were found to be at 45, 60, and some would argue 90 minutes. ACSM (2014) defines an endurance athlete as one who trains and competes for 90 minutes or longer, and for properly fueling before exercise, suggest 30-60 grams of CHO per hour and to take in fuel every 45-60 minutes by consuming a 6-12 oz. sport drink. The significant time points of 45 min, 60 min, 75 min, and 90 min between W and the CHO beverages in the current study correspond to where ACSM suggests implementation of a supplement during prolonged exercise in order to replace glycogen and glucose in the body. The current study shows that the use of a coconut beverage may be just as effective as a leading CHO-beverage in its capability of maintain blood glucose during prolonged exercise. Therefore, the current study shows that the use of a coconut beverage is a viable option to replace and replenish glucose when exercising for a prolonged amount of time.

The observed differences between drinks in this study could be due to the varying CHO amount contained in each drink. The CHO drinks, G and CB, contain different amount of vitamins and minerals which can be found in Table 8.0. The two drinks also contain a different amount of CHO which can be found in Table 9.0. Of the two CHO drinks, G contains more CHO than CB, therefore G theoretically should provide more fuel for the muscles.
Table 9.0

Nutritional Comparison of 250 ml Between Two CHO Beverages

<table>
<thead>
<tr>
<th></th>
<th>Calories</th>
<th>CHO (g)</th>
<th>Sugar (g)</th>
<th>Sodium (mg)</th>
<th>Potassium (mg)</th>
<th>Chloride (mg)</th>
<th>Calcium (mg)</th>
<th>Magnesium (mg)</th>
<th>Phosphorus (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>63</td>
<td>15</td>
<td>14</td>
<td>103</td>
<td>30</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>CB</td>
<td>48</td>
<td>9</td>
<td>6</td>
<td>25-266</td>
<td>634</td>
<td>118</td>
<td>60</td>
<td>63</td>
<td>51</td>
</tr>
</tbody>
</table>

G==CHO-beverage  (Coombes & Hamilton, 2000)
CB=Coconut beverage
The blood glucose difference between drinks could also be due to the amount of CHO intake prior to each trial. In the current study, subject’s displayed differences in the kcal/kg in their diets. All the subjects in the current study were instructed to complete a similar diet before each trial and were given a sample meal to follow. However, subjects consumed roughly an average of 42 kcal/kg prior to their G trial and 37 kcal/kg prior to the CB trial. When broken down into macronutrients the difference for carbohydrates is roughly 0.37g/kg or 37g of carbohydrates. This difference could cause them to have less energy available to the working tissues and therefore be unable to perform as long or at as high of an intensity during the CB trial. However, the difference in consumed CHO prior to testing for trials G and CB could account for the small difference seen in mean glucose levels for W (78.8 mg/dl), G (78.6 mg/dl) and CB (79.89 mg/dl) at baseline. Having the subjects consume the same meal at the same time prior to each study could minimize the difference in glucose levels seen at the beginning of the trials.

There was no significant difference (p=0.965) between glucose levels for W, G, and CB measured at baseline. W was the placebo trial and had no CHO content to provide the body with. Therefore, W had the lowest mean glucose readings at 30 minutes (71.36±8.4), 45 minutes (73.5±9.7), 60 minutes (70.4±9.7), 75 minutes (68.6±9.2) and 90 minutes (67.6±7.5). CB and G both contained CHO and had a greater elevated blood glucose than water at all time points besides baseline and 15 minutes in which G measured slightly lower levels of blood glucose than W. CB had greater blood glucose measurements at all time points when compared with W (Table 2.1). At the time points
baseline and 15 minutes, the subjects had not ingested any beverages as of yet which could be the cause of blood glucose not increasing. However, there was no significant difference at any time point between CB and G (p>0.05). Looking at the type of carbohydrate, many sport drinks contain mixtures of glucose, sucrose, fructose, high-fructose corn syrup, and maltodextrins which can increase the time the beverage sits in the stomach. Coconut beverages are made naturally with fewer additives, which can cause it to empty from the stomach quicker.

The coconut beverage did not elevate blood glucose as high as a leading sport drink and this can be due to the caloric content and CHO concentration of the beverages. Coconut water, which is a main ingredient in coconut beverages, has less CHO per 250 ml than a leading sport drink. The reduction in CHO could lead to less energy available to the body during exercise. There were no significant differences (p=1.000) between the two drinks (G and CB). Therefore, with the electrolyte content of the coconut beverage heavily outweighing the leading sport drinks, it may contribute to hydration status which was not measured in the current study. Replenishing electrolytes are important because electrolytes affect the amount of water in the body, acidity of the blood, along with other important muscle and body functions (Yong et al., 2009).

Both CB and G provided the body with exogenous CHO during the submaximal run. The CHO provided from the drinks were most likely delivered straight to the blood and utilized by the muscles and working tissues. The use of CHO to create glucose and usable energy for the muscles delayed glycogenolysis in the liver and kidneys (Brooks et
al., 2005; Coleman, 1994; Jeukendrup, 2007; McArdle et al., 2007). The delay in the
glycogen breakdown preserves the limited stores in the liver and kidneys for use at a later
time. The glycogen being used at a later time should allow for a longer and more intense
exercise or performance during the CB and G trials when compared to W. There were no
significant differences for TAT times between the three beverages. While W had the
highest TAT average time in seconds (57.2583±21.27), compared to G (57.2108±20.47),
and CB (52.6225±18.63), it also possessed the lowest timed run of 19.81 seconds.

Liver glycogenolysis tends to be reduced when subjects ingest CHO (Brooks et al., 2005;
Jeukendrup, 2007; McArdle et al; 2007). The ingestion of CHO during exercise results in a
smaller increase in both insulin and blood glucose which is thought to prevent a sudden decrease
in blood glucose. The finer control of blood glucose in such situation may be due to an increased
muscle fiber permeability that decreases the need for insulin (Kenney, Wilmore, Costill, 2012;
Wilmore & Costill, 2004). Ingesting a CHO supplement can allow the liver to spare and
conserve glucose for release at a later time. Studies on treadmill running and cycling while
ingesting CHO have shown a decrease in the use of muscle glycogen adding support to what was
previously stated that glycogen can be spared for the end of a workout and contribute late in
prolonging the exercise (Juekendrup, 2004; Juekendrup, 2007; Lamb & Murray, 1999). With the
information given previously, the supplementation of a coconut beverage containing a varied
amount of CHO, like the CB used in the current study, should allow an endurance athlete to save
on utilizing liver and kidney glycogen stores.
Blood lactate was examined for each drink separately across the 90 minutes.

Blood lactate measures followed the same pattern for each drink throughout the 90 minutes. Lactate values stayed very consistent at a low measurement showing little accumulation throughout the 90 minute run. Lactate concentration spiked following the TAT for all three trials (Figure 8.0). The TAT is a high intensity and strenuous bout of running. During the TAT the subjects were working anaerobically, allowing the body to produce more lactate and at a greater rate than it was able to clear. The body is continuously creating and utilizing lactate, this occurs at a greater rate when performing exercise (Brooks et al., 2005).

Once thought to be a metabolic waste, lactate is able to provide a valuable source of energy from accumulation of intense exercise. As mentioned previously, when exercise is at a low enough intensity, the individual can work aerobically and better utilize the oxygen they consume to break down fats and CHO. Being able to better utilize oxygen allows for lactate utilization as an energy source. In contrast, when there is an insufficient amount of oxygen available and the individual is working anaerobically, lactate builds up in the body and the rate of use begins to diminish and the buildup of acidity causes fatigue (Azevedo et al., 2007; Brooks et al., 2005; McArdle et al., 2007; Miller et al., 2002; Wilmore & Costill 2004). There were no significant differences between the three drinks (p>0.05) for measured lactate. This offers evidence that no one trial caused the subjects to exert more effort or work harder. The similarity in lactate
response allows speculation that factors responsible for glucose uptake were also similar between trials (Russell, Benton, Kingsley, 2014).

Stellingwerff et al. (2007) found that during prolonged cycling, when a subject ingested a CHO supplement their lactate values were greater than when a placebo was ingested. As exercise prolonged they found that lactate levels were more elevated during the placebo trial than in the CHO trial. Tsintzas, Williams, Wilson, and Burrin (1996) examined the effects of CHO ingestion during the first hour of treadmill running on endurance capacity. Eleven male subjects ran at 70% of VO$_{2\text{max}}$ to exhaustion. Similar to the current study they found that there was no difference in measured lactate levels. Similar results were found in Coggan and Coyle (1987) who used 7 cyclists and had them exercise at 70% of their VO$_{2\text{max}}$ until fatigue. The cyclists were given glucose during exercise to prolong performance.

There were no significant differences in lactate in the current study. Lactate levels for CB were slightly more elevated than the lactate levels of W. In the research mentioned and the current study, subjects were asked to exercise at 60-70% of VO$_{2\text{max}}$. During the three trials the distance each subject ran was recorded. The mean distance traveled, in miles, when consuming W was 9.82±0.890, for G was 9.92±0.827, and CB was 9.91±0.841. Distance traveled can show that the subjects were able to work slightly harder when consuming a CHO supplement than when W was consumed, although not significant. This small increase in work may also account for the slight increase in lactate during the 90 minute run when consuming a CHO supplement.
In endurance trained athletes, much like the ones who took part in the current study, the ability to shuttle lactate to muscle tissues which are able to utilize the molecule (Type I muscle fibers) increases. Throughout the submaximal 90 minute run mean lactate measurements never increased above 2.00 mmol (Figure 8.0). The failure of increase in lactate could be due in part that the subject’s in this study were all aerobically trained athletes. The subjects were able to utilize the produced lactate and use it as a fuel source disallowing any large accumulation throughout the run. The absence of accumulation of lactate shows that the subjects were providing enough oxygen to their body so as to not enter anaerobic glycolysis during the run. After the TAT there is a sharp increase in lactate due to the subjects performing an anaerobic exercise activity. The increase in lactate observed may have been caused by the subjects’ inability to clear lactate due to inefficient oxygen consumption. Therefore the rate of appearance was much greater than the rate of clearance which is typically seen during high intensity anaerobic bouts of exercise (Brooks et al., 2005).

There were a few limitations to the present study. The first limitation was the limited sample size (N=11), which resulted in insufficient power. A power analysis has indicated a larger sample of at least 15 subjects should be used in future research. Another limitation to the current study was subject compliance due to scheduling conflicts. Many of the subjects had their trials held at different times during the day throughout the study due to their work or class schedule. This could have an effect on their fatigue levels depending on sleep, hormone levels or how much activity they took part in throughout the day. Hormones, such as insulin and glucagon, fluctuate throughout the day which could have an impact on blood glucose. Subjects were also
asked to maintain a 24 hour food log as well as eat a standardized meal 2 hours prior to testing to assure similar glucose and lactate baseline points for each trial. As discussed earlier, there was a difference found in consumption of CHO between the G and CB trials. The difference in consumption of CHO should be carefully looked at in future studies. While the subjects were advised not to run 24 hours prior to testing, some were training for marathons and refused to stop their training. The rest between trials between subjects were different due to scheduling conflicts. We attempted to control for this, but was not often achieved. Each subject had at least 48 hours in between tests. However some waited up to a week between tests. This time difference could have an effect on their recovery and performance.

Direction for future research would be to include a larger sample size. The present study can be used as a preliminary test to suggest a coconut beverage maintains blood glucose just as well as a leading sport carbohydrate-electrolyte drink. Future research should also look into using the more professional endurance athletes such as elite cross country runners and professional athletes who presumably have more training then those used in the current study. The more professional endurance athletes are able to compete at a higher intensity for a longer amount of time because their bodies are able to break down fats at higher intensities. Elite cross country runners and professional athletes are able to utilize fat oxidation at higher intensities when compared to amateur runners (i.e Athlete’s paradox) (Dube, Amati, Stefanovic-Racic, Toledo, Sauers, & Goodpaster. 2008). The athlete’s paradox could have an effect on how and when glycogen is broken down and the need for CHO supplementation. The inclusion of elite runners, and those with similar experience and age will control the variability in oxidative
capacity and running economy. Running economy can have an influence on energy burned and how hard one is working. Those who have been training and running for 20 years will have a difference in running style then those who have just began running. Taking elite runners will control for the disparity in running economy among amateur runners.
CONCLUSION

In conclusion, the present study investigated the effects of a coconut beverage on blood glucose and lactate. The results of the current study indicate during a submaximal treadmill run of 90 minutes, there is a significant difference between blood glucose for W and CB at minutes 45 and 90. There is also a significant difference between W and G at minutes 45 and 60. However, there was no significance at any time point between CB and G. Consumption of CB may be a better option to replace electrolytes compared to G due to the concentration of electrolytes found in coconuts and hence maintain hydration better than G. Therefore, the current study shows that the use of a coconut beverage is a viable option to replace and replenish blood glucose when exercising for a prolonged amount of time.
REFERENCES


Do you run for exercise?
Are you interested in learning your VO₂max?

VOLUNTEERS NEEDED!
If you are...
⇒ Male
⇒ Ages 18-45
⇒ Comfortable running long distances
⇒ A Non-smoker

...You may qualify for a graduate student research study on beverage supplementation and running performance!

Volunteers will complete a VO₂max test, 3–90 minute running trials, 24 hour food logs, and anthropometric measurements over a 2 week period. Each of the 4 appointments will last ~120 min.

Benefits of participation:
• VO₂max Results & Analysis
• Body Composition Analysis

Contact
rnguyen2@niu.edu or jalis1@niu.edu if you are interested!

Northern Illinois University
College of Health and Human Sciences
Family, Consumer, and Nutrition Sciences
Nutrition and Dietetics
Recruitment Letter

Hello!

You are invited to take part in a study regarding beverage supplementation and running performance. Dr. Judith Lukaszuk, a Professor in Nutrition and Dietetics at Northern Illinois University (NIU), Rayanne Nguyen, a graduate level nutrition student and dietetic intern at NIU, and Josh Alis, a graduate level exercise physiology student at NIU are conducting this study. We would like to determine if consuming beverages during exercise influences performance outcomes. You were selected because of your position as a physically active male and your willingness to participate.

If you decide to participate in this study, you will complete a short survey on demographics, dietary habits, vitamin and mineral supplement intake, and medical history. You will be asked to complete a series of runs on a treadmill and anthropometric measurements over a span of four weeks. There will be one VO\textsubscript{2max} test, three 90 minutes runs at 60-70% VO\textsubscript{2max} with beverage consumption at 15 minute intervals, in addition to three sprint threshold anaerobic test efforts. Each session in the performance lab will take approximately 2 hours to complete, and there will be one per week for four weeks. All information will be kept confidential; your name will not be used on the final report or associated with any data. Only Northern Illinois University qualified research personnel will see the data and/or be present at the time of the study. All names and any other identifying information will be removed upon data entry.

The risks from participating in this study include soreness, fatigue, physical exertion, and potential injury. Your participation in this study is completely voluntary and you may refuse to participate or withdraw at any time.

If you have any further questions, please don’t hesitate to contact the graduate student researcher, Rayanne Nguyen, at rnguyen2@niu.edu, Josh Alis, at jalis1@niu.edu or Dr. Judith Lukaszuk, thesis committee chair, at jmlukaszuk@niu.edu. Questions about rights of research subjects and research related injury should be directed to the Research and Compliance Integrity Office at researchcompliance@niu.edu.

You will be provided with a copy of this form to keep for your records. Your signature indicates that you have decided to participate in this study having read the information provided.

Thank you for your time.
APPENDIX B

CONSENT FORM
Consent Form

I do hereby consent to take part in the study regarding the effect of beverage supplementation on exercise performance by researchers at Northern Illinois University. Dr. Judith Lukaszuk, a Professor in Nutrition and Dietetics at Northern Illinois University (NIU) and Rayanne Nguyen, a graduate level nutrition student and dietetic intern at NIU are conducting this study. I have been informed that the purpose of the study is to compare beverage supplementation and running performance.

I understand that as a subject of the study, I will complete a short survey that includes information about demographics, dietary habits, vitamin and mineral supplement intake and past medical history, have my height, weight, and body composition measured. I understand this study will also involve completing a series of runs on a treadmill over a span of four weeks. There will be one VO\textsubscript{2max} test, three 90 minutes runs at 60-70% VO\textsubscript{2max} with beverage consumption at 15 minute intervals, in addition to three sprint threshold anaerobic test efforts spread out over four weeks. I understand that all collection of this data will take place in the Exercise Physiology lab in Anderson Hall at Northern Illinois University and each appointment will take approximately 120 minutes total.

I understand that my participation is voluntary and I may withdraw from this study at any time without penalty or prejudice and if I have any additional questions concerning this study, I may contact Rayanne Nguyen at (805) 680-1376 or her advisor Dr. Judith Lukaszuk at (815) 753-6352. I understand that if I wish to obtain further information regarding my rights as a research subject, I may contact the Office of Research Compliance at Northern Illinois University at (815) 753-8588.

I understand that all records are held in confidence and that my name will not be used on the final report or associated with any data. Only Northern Illinois University qualified research personnel will see the data and/or be present at the time of the study. Any information obtained in connection with this study and that may identify me individually will be kept confidential at all times.

I understand that the benefits of this study include determining my body composition and my VO\textsubscript{2max}. I will also be offered nutrition counseling at the end of the study. I understand that these tests and counseling are to be at no charge to me.

I understand that the risks from participating in this study include soreness, fatigue, physical exertion and alteration of dietary and activity patterns. The discomfort will typically go away after a few days. Northern Illinois University policy does not provide for compensation for, nor does the University carry insurance to cover injury or illness incurred as a result of participation in University sponsored research projects. Upon suffering a minor injury, subjects will be
referred to their PCP, NIU Health Services, or the nearest hospital and in the event of serious injury, emergency medical services will be notified immediately.

I understand that my signature below is consent to participate in the beverage supplementation and exercise performance study. I understand that my consent to participate in this project does not constitute a waiver of any legal rights or redress I might have as a result of my participation, and I acknowledge that I have received a copy of this consent form.

Subject Name_______________________________
Subject Signature ____________________________
Date ___________________
Signature of Investigator ______________________
APPENDIX C

MEDICAL HISTORY FORM
Medical History Questionnaire

Subject Name: ____________________________ Date: ___________________

Age: _________  Gender: ________ Height: _________ Weight: _______

Do you smoke?        YES  NO
Do you have any allergies (foods, latex, plants, animals, etc)?  YES  NO
    If yes, please list: ____________________________________________

Do you have an implanted electronic device (pacemaker, etc)?  YES  NO

Have you been diagnosed with, or have you experienced any of the following?  (Check all that apply)

    _____ Cardiovascular disease or heart attack
    _____ Diabetes or prediabetes
    _____ Hypertension (high blood pressure)
    _____ Hypercholesterolemia (high cholesterol)
    _____ Metabolic syndrome
    _____ Thyroid or endocrine disorder
    _____ Osteopenia or osteoporosis
    _____ Asthma or breathing difficulties
    _____ Gastrointestinal disorders
    _____ Liver or kidney disease
    _____ Pain or discomfort in chest, neck, or jaw during exercise
    _____ Shortness of breath at rest or with mild exertion
    _____ Dizziness or fainting
    _____ Difficulty breathing when lying down or during sleep
    _____ Heart rate irregularities or heart murmur
    _____ Acute cramping or muscle pain
    _____ Family history of heart disease

Do you currently take any supplements (including caffeine)?  YES  NO
    If yes, please list: ____________________________________________

Do you have any dietary restrictions (including allergies, personal preferences)?  YES  NO
    If yes, please explain: _________________________________________

How many days a week do you exercise? _________ For how long? _________
What type of exercise do you do? _______________________________________

How often do you choose running for your physical activity? (circle one)

    0-2 days/week          3-4 days/week          5-7 days/week

Are you comfortable running for 90 minutes?  YES  NO
APPENDIX D

ACSM’S GUIDELINES FOR EXERCISE TESTING & PRESCRIPTION
<table>
<thead>
<tr>
<th>POSITIVE RISK FACTORS</th>
<th>DEFINING CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Men ≥45 yr; Women ≥55 yr</td>
</tr>
<tr>
<td>Family History</td>
<td>Myocardial infarction, coronary revascularization, or sudden death before 55 yr of age in father or other male first-degree relative, or before 65 yr of age in mother or other female first-degree relative</td>
</tr>
<tr>
<td>Cigarette Smoking</td>
<td>Current cigarette smoker or those who quit within the previous 6 months or exposure to environmental tobacco smoke</td>
</tr>
<tr>
<td>Sedentary Lifestyle</td>
<td>Not participating in at least 30 min of moderate intensity (40%-60% VO2R) physical activity on at least three days of the week for at least three months (20,23)</td>
</tr>
<tr>
<td>Obesity&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Body mass index ≥30 kg . m² or waist girth ≥102 cm (40 inches) for men and ≥88 cm (35 inches) for women (2)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Systolic blood pressure ≥140 mm Hg and/or diastolic ≥90 mm Hg, confirmed by measurements on at least two separate occasions, or on antihypertensive medication (10)</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>Low-density lipoprotein (LDL-C) cholesterol ≥130 mg . dL-1 (3.37 mmol - L-1) or high-density lipoprotein (HDL-C) cholesterol &lt;40 mg . dL-1 (1.04 mmol - L-1) or on lipid-lowering medication. If total serum cholesterol is all that is available use ≥200 mg . dL-1 (5.18 mmol - L-1) (3)</td>
</tr>
<tr>
<td>Prediabetes</td>
<td>Impaired fasting glucose (IFG) = fasting plasma glucose ≥100 mg . dL-1 (5.50 mmol - L-1) but _&lt;126 mg . dL-1 (6.93 mmol - L-1) or impaired glucose tolerance (IGT) = 2-hour values in oral glucose tolerance test (OGTT) ≥140 mg . dL-1 (7.70 mmol - L-1) but &lt;200 mg . dL-1 (11.00 mmol - L-1) confirmed by measurements on at least two separate occasions (8)</td>
</tr>
</tbody>
</table>

**NEGATIVE RISK FACTOR**

| High-serum HDL cholesterol<sup>+</sup> | ≥60 mg . dL-1 (1.55 mmol - L-1) |
† Note: It is common to sum risk factors in making clinical judgments. If HDL is high, subtract one risk factor from the sum of positive risk factors, because high HDL decreases CVD risk.

“Professional opinions vary regarding the most appropriate markers and thresholds for obesity; therefore, allied health professionals should use clinical judgment when evaluating this risk factor. (http://certification.acsm.org/certreview3)
APPENDIX E

SAMPLE 24 HOUR INTAKE FORM
24 Hour Dietary Intake Form

Subject: _____________________ Date: ___________________ Trial #: _______

Please complete the following by:

- Indicate the time of consumption in the left column
- Indicate the foods and beverages consumed along with estimated measurements (cup, ounce, tablespoon, etc) in the right column

Please write everything consumed in the past 24 hours leading up to this trial.

<table>
<thead>
<tr>
<th>Time</th>
<th>Food/Beverage Consumed &amp; Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example:</td>
<td>2 slices whole wheat bread (Hy-Vee brand)</td>
</tr>
<tr>
<td>7:15 am</td>
<td>8 oz 2% milk</td>
</tr>
<tr>
<td></td>
<td>1 medium Fuji apple</td>
</tr>
<tr>
<td></td>
<td>1 poached egg</td>
</tr>
</tbody>
</table>

Please list any supplements (including caffeine) consumed in the past 24 hours leading up to this trial below.

____________________________________________________________________________
____________________________________________________________________________
APPENDIX F

DATA COLLECTION FORM
Data Collection Form

Subject: _____________________ Date: ______________ Trial #: _______
Age: _____________________ Height: _____________________ Gender: _______
Before Weight: _______ IWC: _______ EWC: _______ % Body Fat: _______

VO₂max:

Lab Temperature: _______ Humidity: _______

<table>
<thead>
<tr>
<th></th>
<th>Beverage Consumption (fl oz)</th>
<th>Treadmill speed</th>
<th>Treadmill % grade</th>
<th>Heart rate (BPM)</th>
<th>VO₂ (ml/kg)</th>
<th>Respiratory Exchange Ratio - RER</th>
<th>Rate of Perceived Exertion - RPE</th>
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<tbody>
<tr>
<td>Baseline</td>
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<td>Treadmill Anaerobic Test - TAT</td>
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<tr>
<td>5 min rest</td>
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<tr>
<td>10 min rest</td>
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</tbody>
</table>

GI/distress comments:

TAT Time:

After Weight: _______ IWC: _______ EWC: _______
APPENDIX G

OMNI-RPE SCALE
Instructions for ratings of perceived exertion (RPE).
On the next pages, there are scales for you to rate your perceived exertion level. Perceived exertion is the overall effort or distress of your body during exercise. The number 0 represents no perceived exertion or discomfort and the number 10 represents the greatest amount of exertion that you have ever experienced.

At various times during the exercise test and with every time you exercise you will be asked to point at or state the number that best represents your rating of perceived exertion at the time. You will also be asked to record these numbers on your exercise log with every aerobic and resistance training session at home. Remember, it is a measure of how you feel overall, not just how one part of your body might feel.

When selecting a number, look first at the words on the table and then indicate the number that corresponds to how you are feeling.

There are no right or wrong answers so simply select the number that you feel best represents how you are feeling at that point in time.

Please select from the following RPE scales – the one on strength and the one on aerobic exercise.

**OMNI-RPE scale for aerobic exercise**
APPENDIX H

REVIEW OF LITERATURE
REVIEW OF LITERATURE

In today’s society, athletes are looking to gain a competitive edge on their competition, which causes them to explore trends and fads that claim to enhance athletic performance or at the least prolong athletic activity. An ergogenic aid is the use of an exogenous beverage or nutrients via food that can enhance performance capacity, performance efficiency, ability to recover from exercise, or the quality of training (Kreider, 2003; Brooks, Fahey, & Baldwin, 2005). The competitiveness of the sports world has driven athletes to utilize any substance that may provide them with an advantage over their competition. While many companies have produced what they considered top of the line ergogenic aids, a vast majority are simply placebos. Placebos cause an improvement in performance simply through suggestion and have no true effect on the athlete (Brooks et al., 2005). Marketing of ergogenic aids has increased their use in athletes of all ages. When one evaluates the proposed value of an ergogenic aid it is important to observe the theoretical rationale, scientific evidence of the proposed aid affecting metabolism/exercise performance, research design, and the reliability of the experimental methods used (Kreider, 2003).

All forms of movement performed by the body can be classified as an energetic event which requires a source of energy. The immediate and most familiar source of energy in the body comes from adenosine triphosphate (ATP) which is formed from the breakdown of glucose from which we receive from carbohydrates, fats, and proteins in everyday diets (Brooks et al., 2005; McArdle, Katch, & Katch, 2007). ATP is formed from an adenine base which attaches to a ribose, a 5-carbon sugar, and connects to three phosphate tails. It is when one of the three tails is
cleaved off that energy is released to the muscle to perform work (Brooks et al., 2005; McArdle et al., 2007). The degradation of ATP is performed by enzymes called ATPases and since the splitting of the phosphate tails involves water, the splitting is referred to as hydrolysis (Brooks et al., 2005). In the normal muscle tissue ATP concentrations are quite low which is advantageous because any small utilization will automatically stimulate energetic processes which generate ATP (Brooks et al., 2005).

With the onset of high intensity exercise, ATP stores in the muscle are depleted in 3-5 seconds. Phosphocreatine is the first energetic pathway to help resynthesize ATP. However, phosphocreatine stores deplete at around 40 seconds into exercise. The next pathway to provide ATP is glycolysis, therefore the utilization of blood and liver glucose is important in maintaining prolonged activity. At a low to moderate intensity training the body will rely mostly on fats through beta-oxidation in order to produce the needed ATP. When the training intensity increases to high intensity the body shifts its reliance to CHO due to its quicker breakdown (Brooks et al., 2005; McArdle et al., 2007). If the body is able to limit the decrease or blunt the usage of liver glucose then it can save the reserves in the liver for use at a later time which theoretically should prolong exercise.

**GLUCOSE**

Glucose, also known as dextrose or blood sugar, is a 6 carbon compound that forms naturally in the body by digestion of more complex carbohydrates (McArdle et al., 2007). Glucose is needed to perform everyday functions, it is required by the central nervous system,
organs, and cells in order to function properly. Normal blood glucose is around 100 mg/dl in postabsorptive humans and is continually changing throughout the day. Muscles will increase their need for glucose during exercise in order to perform a desired action. The muscles will take glucose which is already in the blood due to its quick and easy availability. Once blood glucose decreases the liver, which is the main organ of glucose production, must increase from approximately 1.8 mg/kg body weight/min to a much higher output in order to keep a homeostasis level in the blood. This initial increase will usually show as a spike in blood glucose at the onset of exercise and level off over a period of time and possibly even falling but always staying in within 10% of baseline value until cessation of exercise (Brooks et al., 2005; Aulin, Söderlund, & Hultman, 2000).

Glucose is broken down through Glycolysis and the Tricarboxylic Acid (TCA) cycle in order to produce ATP. Glycolysis uses CHO to resynthesize ATP. Glycolysis however is not as rapid in the rate in which it resynthesizes ATP compared to the phosphagen system, however the capacity is much larger due to the amount of CHO present compared to creatine. The product of Glycolysis is pyruvate which in turn can be converted to lactate in which ATP is resynthesized at a quicker rate for a shorter duration, or pyruvate can be shuttled into the mitochondria where if intensity is low enough the duration of the process can increase while the rate of ATP synthesis decreases (Baechle & Earle, 2008).

Glucose first goes through glycolysis where it may either enter as glucose or glycogen, which is the stored form of glucose in the body. Glycolysis begins breaking down glucose/glycogen by using energy from ATP in order to break down the glucose molecule. If the
glucose molecule enters glycolysis from glycogen then one less ATP is needed in glycolysis. As
the molecule moves through glycolysis it will end up yielding 4 ATP and 2 Nicotinamide
Adenine Dinucleotides (NADH). While the formed NADH molecules will move on to the
electron transport chain the end product of glycolysis is Pyruvate which is sent to the TCA cycle
(Brooks et al., 2005; McArdle et al., 2007; Kenney, Wilmore, Costill., 2012).

The TCA cycle will “turn” two times for every 1 molecule of glucose broken down. From
both Pyruvate acids formed from the one glucose molecule, there will be a total of 6 NADH, 2
Flavin adenine dinucleotides (FADH) and 1 ATP. Each NADH formed through glycolysis and
the TCA cycle will yield 3 ATP while each FADH will yield 2 ATP. There are differences in the
literature of how many total ATP is yielded through glycolysis, the TCA cycle, and the electron
transport chain, but all claim it to be around 36-38 ATP (Brooks et al., 2005; McArdle et al.,
2007; Kenney et al., 2012).

CARBOHYDRATES

Carbohydrates (CHO) are macronutrients which are composed of the elements carbon,
oxygen, and hydrogen and can be classified into three groups depending on the number of sugar
units they contain (Monosaccharides, Disaccharides, and Polysaccharides). The
Monosaccharide's represent the most basic unit of CHO and contain glucose, which is the
building block of the larger sugars. Disaccharides consist of 2-10 monosaccharides, while
polysaccharides define the combination of three to thousands of sugar molecules (Baechle &
Earle, 2008). Glucose can be found in the blood and consists of a 6-carbon compound. After
glucose is absorbed in the small intestine it has 3 options: (1) be used as energy source right away, (2) form glycogen in the muscle and liver or (3) convert to fat for a later use (McArdle et al., 2007).

CHO serve four energy metabolism and exercise performance related functions in the body. First they act as an energy source, CHO can be found and stored in the liver (~100 g) and in skeletal muscle (~350-700g). These CHO stores represent a small amount of the total energy storage of the body (<5%), however muscle glycogen represents an essential fuel source during prolonged exercise at low, moderate and high intensities (Cermak & van Loon, 1994). The depletion of endogenous CHO stores are the primary limiting factor in prolonged endurance exercise, so many have studied the effects of consuming CHO before and during exercise to evaluate performance of athletes. It was first proposed in the 1920’s that ingestion of CHO during exercise would cause an improvement in performance and has since been generally accepted (Currell & Jeukendrup, 2007).

Secondly, CHO serve as a protein sparer. Proteins are important in tissue maintenance along with repair and growth and if glycogen stores become depleted the body begins to synthesize glucose from amino acids which in turn strain the body’s protein levels. CHO also serve as a metabolic primer in that they assist with fat oxidation. If there is not enough glycogen breakdown then fats will not metabolize all the way and acetyl-CoA will accumulate from beta-oxidation and in turn cause ketosis, or an elevation in ketone bodies causing the blood pH to become more acidic. Finally CHO provide fuel for the Central Nervous System (CNS-brain and
spinal cord). The main source of energy for the brain is blood glucose so depletion of CHO can have severe affects upon the CNS (McArdle et al., 2007).

CHO supplementation has been believed to increase endurance performance by reducing the body’s reliance on limited endogenous stores. If someone supplements with CHO the increase in endurance is likely achieved by maintaining or raising plasma glucose concentrations and sustaining high rates of carbohydrate oxidation. Oxidation refers to the transfer of hydrogen atoms, oxygen atoms, or electrons (Jeukendrup, 2007). Endogenous stores refers to the collections of CHO or fats within the body that can be used for energy during exercise or when needed. When a person begins to exercise an increase in glucose as a fuel has been observed (McArdle et al., 2007). The increased blood flow allows for an increase in the availability of glucose via blood, glucose is also made readily available by the breakdown of intramuscular glycogen (Baechle & Earle, 2008). The increase in blood flow to the muscles is due to the rhythmic contractions of the muscle causing constriction and dilatation of arteries and veins as well as an increased cardiac output.

CHO is usually the most important fuel for muscle exercise (Brooks et al., 2005). During early moderate exercise it has been found that plasma glucose provides around 1/3 of CHO oxidation while muscle glycogen accounts for the other 2/3. However, as exercise continues a shift can be seen as plasma glycogen increases and muscle glycogen decreases (McArdle et al., 2007). This is what leads to fatigue, as exercise is prolonged the decline in muscle glycogen as well as plasma glucose. If an athlete supplements with CHO during exercise they will allow more CHO to be available in the plasma therefore increasing the time they are able to perform at
that intensity (Lamb & Murray, 1999). Liver glucose output levels have been found to be reduced when subject’s ingest CHO, this can be due to a observed decrease in blood glucagon which is responsible for raising the blood glucose levels. This strategy can allow the liver to spare and conserve glucose for release at a later time. Lamb and Murray (1999) showed that while running on a treadmill with CHO intake, there was a decrease in the use of muscle glycogen proving what was previously stated that glycogen can be spared for the end of a workout and contribute late in prolonging the exercise (Lamb & Murray, 1999).

The consumption of CHO has been shown to have no effect on strength, power, or high-intensity exercise, however carbohydrate ingestion during prolonged (>90 min) continuous exercise has had its benefits well documented in that it consistently shows a delay in fatigue (Ali, Williams, Nicholas, & Foskett, 2007). During low to moderate intensity fat dominates as the preferred energy source of the body, however CHO is an essential fuel source during prolonged exercise (Cermack & Van Loon, 2013). So the uptake of extra CHO could possibly help in the breakdown of fats which pound for pound contains more energy than CHO and proteins. Jeukendrup (2004) says that performance benefits have been present when subjects ingest relatively small amounts of CHO (16g/h), while Bosch (2007) says that at least 13g/h are enough to see an ergogenic effect. Other authors have reported that intakes of 30-60 g/h are required to elicit a better performance when compared to no CHO intake (Currell & Jeukendrup, 2007; Cermak & van Loon, 2013; Coleman, 1994; Lamb & Murray, 1999; Jeukendrup, 2007). Lamb and Murray (1999) conclude that an intake rate of 13g/h is too small to alter a hormone response or time to fatigue. It has been shown that higher oxidation rates occur when a mixture of CHO
are ingested when compared to a single CHO supplementation. This is believed to happen as a result of the mixture of CHO acting on different absorption pathways so that no single pathway becomes saturated (Bosch, 2007; Cermak & van Loon, 2013; Currell & Jeukendrup, 2008; Jeukendrup, 2004, 2007).

While there are many performance factors that are not within an athlete’s control (age, genetics, and weather), athletes can control their nutrient, fluid, and supplement intake, as well as their training regimen. Many collegiate athletic and professional teams are hiring and consulting with Exercise Physiologist, Registered Dietitian Nutritionists (RDN) and those certified specialists in sports dietetics (CSSD) as they see the impact of proper nutrition and training on game day outcome, energy levels, performance, and effort (Wallinga, Takahashi, Kohnke, Koszewski, Hingst, & Socha T.2013).

The ACSM educates consumers saying “carbohydrate consumption helps to sustain and improve exercise performance during high intensity exercise longer than one hour [as well as lower intensity for longer periods]” in addition to helping replenish glucose/glycogen stores and accelerate rehydration (Simpson & Howard, 2011). Glycogen stores and CHO typically make up the primary fuel source for the body during aerobic exercise (Kenney et al., 2012). Glycogen depletion and low blood glucose can limit performance and be a source of fatigue in exercise lasting 60-90 minutes (Kenney et al., 2012). Repeated exercise without replacing the body’s glycogen stores can lead to fatigue and decreased performance over time (Saltin, 1973; Reilly & Ekblom, 2005; Campbell, Prince, Braun, Applegate, Casazza, 2008).
The brain almost exclusively uses blood glucose as a fuel source. So as the active muscle continues to utilize glycogen even when levels are low, the CNS suffers from this low level of glycogen. When blood glucose decreases to a low level (<45mg glucose per deciliter of blood) one is said to be hypoglycemic. Hypoglycemia typically brings on feelings of weakness, dizziness, and hunger which in turn will decrease the performance of the athlete (McArdle et al., 2007). If Hypoglycemia continues for an extended amount of time serious side-effects can occur due to depriving the brain of its fuel source. CHO intake could indirectly lower the amount and influence of exercise induced tryptophan in the blood plasma. This is done by reducing the amount of lipolysis, the breakdown of fats, from free fatty acids in the blood. The decrease in tryptophan uptake by the brain is believed to coincide with attenuation in the production of serotonin both believed to be part of fatigue (Lamb & Murray, 1999).

Athletes are told to consume a high CHO diet to ensure they have plenty of CHO stored to prolong performance. They also try to consume adequate amounts during performance and after to replenish their energy stores. The International Olympic Committee stated that “Athletes should aim to achieve carbohydrate intakes that meet the fuel requirements of their training programs and also adequately replace their carbohydrate stores during recovery between training sessions and competition. This can be achieved when athletes eat carbohydrate-rich snacks and meals that also provide a good source of protein and other nutrients.” This came about by several studies suggesting that subjects found exercise to be easier if they had consumed a CHO-rich diet compared with a diet composed of mostly fat (Jeukendrup, 2004).
When CHO get broken down through glycolysis as mentioned previously they produce two molecules of pyruvate. During light to moderate exercise there is a sufficient amount of oxygen to perform aerobic glycolysis. The oxygen molecules bind with the hydrogen ions released from the substrates to form water. During high strenuous exercise the demand for oxygen exceeds that of its supply. The hydrogen ions become in excess and pair up. When these hydrogen ions pair up they attach to the pyruvate molecules formed to create lactate. This newly formed molecule must first be catalyzed by the enzyme lactate dehydrogenase before a lactate molecule is produced (McArdle et al., 2007).

**LACTATE**

Lactate is a three carbon molecule which is formed by pyruvate through reduction by the enzyme lactate dehydrogenase (McCardle et al., 2007). Lactate was once thought to be an end product and metabolic waste from exercise, however studies have recently shown that it can be a great energy source and fuel for the muscles of the body. It is able to be used in the muscle as well as being moved to the heart where it is a main source of fuel as well as the liver where it serves as a gluconeogenic precursor (Azevedo, Tietz, Two-Feathers, Paull, & Chapman, 2007). Lactate is an intermediate in CHO oxidation and is formed when the rate of pyruvate clearance is exceeded by the rate of pyruvate appearance (McArdle et al., 2007). Both lactate and pyruvate each possess a carboxyl group which at the pH of the human body will dissociate hydrogen atoms (Brooks et al., 2005).
The muscle is one of the primary sites of lactate production as well as shuttling and oxidizing lactate, lactate can also be produced through red blood cell energy metabolism (Miller et al., 2002; McCardle, et al., 2007). Though skeletal muscle is one of the top end producers of lactate in the human body the ability for the muscle to transport the lactate accumulation is of utmost importance to the function of the muscle and the entire body as a whole. Lactate is unable to travel freely in the body therefore it needs help when crossing the muscle membrane (sarcolemma) and the capillary membrane. To transverse these barriers lactate is assisted by monocarboxylate transporters (MCT) 1 and 4. MCT1 can most commonly be found in type 1 oxidative muscle fibers, whereas MCT4 has no dependent muscle fiber. In trained humans the ability and rate of transport of MCT can increase in mostly MCT1 (Brooks et al., 2005).

When lactate is formed in the blood or in the muscle it must be moved to a source that can best utilize lactate as a substrate. There are few different ways this can be done. Lactate is carried and shuttled to neighboring muscles by way of the blood, so blood flow is very important when it comes to the ability of lactate exchange in the body. If blood flow is increased than it will increase lactate deliverance to neighboring muscles, which are able to utilize lactate as an energy source therefore maintaining a more favorable lactate concentration gradient (Gladden, 2000).

When lactate is formed it is delivered to different components of the cell via the intracellular lactate shuttle. Lactate shuttling among cells allows glycogenolysis in one cell to supply other cells with fuel for oxidation (McArdle et al., 2007). The intracellular lactate shuttle has three main components behind it: 1) lactate is directly oxidized by mitochondria without
prior conversion of lactate to pyruvate, 2) the mitochondria has an abundance of mitochondrial lactate dehydrogenase (MLDH) within itself, and 3) the presence of monocarboxylate transporter (MCT) 1. This idea goes on to suggest that lactate which was formed by a reduced pyruvate is carried into the mitochondria via MCT1 where it is acted upon by MLDH, therefore through oxidation the lactate returns to a pyruvate which is then placed into the TCA cycle of the mitochondria.

Another form of lactate shuttling is cell-to-cell lactate shuttle which is simply put exchange of lactate between red and white muscle cells or type I and type II muscle cells. It hypothesizes that the shuttling of lactate throughout the vasculature provides a significant source for oxidation and gluconeogenesis during rest and exercise. So lactate produced in one muscle type can be shuttled to and utilized by a more efficient muscle type. Most commonly this would take place as lactate from glycolytic fiber being shuttled to an oxidative fiber. This means that lactate can be sent all over the body to highly oxidative fibers such as the heart which uses lactate as one of its top fuels. The brain has even been shown to take up large amounts of lactate from the blood and use it as an energy source (Gladden, 2000; Brooks, 2000).

Brooks (1985) concluded that lactate supplementation during exercise is based on the observation that during exercise carbon skeletons originating from muscle glycogen are shuttled among the working muscle in the form of lactate. Most lactate released from one muscle appears to be oxidized within another muscle with only a minimal portion being converted to glucose in the liver (Brooks, 1985; Brooks 1991). Exogenous lactate could have the advantage of fewer disturbances in the endocrine response to exercise, to be independent of insulin for entering the
working muscle, and to be readily available to enter the Kreb’s cycle and reducing equivalents (Roth, 1991). Since lactate is not insulin dependent, lactate oxidation can occur much faster than glucose oxidation, thus providing energy at a faster rate. If lactate produces energy at a faster rate, then lactate would be the preferred source of energy.

A study done by Fahey, Larsen, Brooks, Colvin, Henderson, and Lary (1991) looked at the intake of a polylactate prior and during exercise. They found that the consumption of a polylactate may help maintain blood glucose and enhance blood buffering capacity for long bouts of exercise. They suggest the lactate being produced and ingested act as a glucose and glycogen sparer.

Brooks et al. (2005) looked at the muscle as a consumer during exercise and found that, in a leg, resting muscle produces lactate slowly. They then saw that the amount of lactate concentration in the blood increased radically as exercise began but began to decline as exercise progressed. Gladden (2000) spoke similarly by saying that the rate of lactate appearance increases and the rate of disappearance decreases with short high intensity work causing an increase in net lactate output. However when the intensity is mild to moderate for a prolonged duration of time there is a net lactate uptake because the muscles which are performing at a moderate intensity are able to utilize the lactate as an energy source. He also believes that lactate can be utilized better at higher intensities after the muscle has gone through a warm up.

A study done by Azevedo et al., (2007) performed a test where they took 6 fit male subjects and had them perform five 90 minute trials at 62% of their VO2 peak followed by a high intensity exercise that lasted until volitional fatigue. For three of the trials the subjects ingested a
lactate supplement, Cytomax, while in the other two they ingested a leading sport drink. They found that 15 minutes after the high intensity exercise the subjects blood lactate levels returned very near to their resting levels.

Fahey et al., (1991) took five trained cyclists and had them perform four bouts of exercise. The first exercise was a baseline exercise in which they determined the basis of the intensity each rider would be assigned throughout the next three trials. The endurance trials were performed for 180 minutes and they were required to perform at 70 rpm and a power output of 50% of VO2 peak. The riders consumed a placebo drink, a glucose polymer, or a polylactate. What they found was that blood lactate remained low during all three protocols. They believed that the polylactate could play a role in helping to maintain blood glucose and increase blood buffering capacity during prolonged exercise.

COCONUT WATER

The heavily marketed CHO-beverages (CE) are recommended and seem to be the drink of choice for most athletes, however the high consumption of such beverages are due in part to the widespread marketing campaigns put on by the large sport nutrition and beverage companies. With more and more athletes becoming educated on nutrition and the use of exogenous products such as sport drinks, many individuals are looking to reduce the amount of manufactured sport drinks and increase their intake of more natural alternatives. Many of the familiar sport drinks contain fructose, maltodextrin, artificial flavors, sweeteners and added electrolytes (i.e. sodium & potassium) (Kalman, Feldman, Krieger, & Bloomer, 2012). One such alternative which is
more natural and less processed is coconut beverage (CB). For a nutritional comparison between CB and a top end CHO-beverage (G), see Table 9.0 in Discussion chapter of text.

Coconut water products which have launched globally grew 540% in the past five years (Food Manufacture, 2014; Cernivec, 2014). In the United States, the number of coconut waters released between 2012 and 2013 rose 92% (Cernivec, 2014). Coconut water is naturally occurring, very rich in potassium, contains sodium, and chloride which is not only vital to exercise recovery but also viewed as a hydrating beverage of choice in certain parts of the world (Kalman et al., 2012; Coco5 website 2012). Typically, coconut water contains fewer additives and no high fructose corn syrup as compared to some standard sports drinks (Coco5 website 2012). Coconut water is reported to have antioxidant properties aiding in neutralizing reactive oxygen species resulting from long duration exercise (Kalman et al., 2012).

There is an absence of research connecting the consumption of coconut water with improved exercise performance or recovery. However, people in more humid climates such as the Middle East, South America, and Southeast Asia have been drinking different varieties of coconut water for years (Challem, 2009). Therefore, there have been some studies in relation to coconut water as a rehydrating solution in dehydrated patients or those with gastrointestinal distress (Kalman et al, 2012; Saat, Singh, Sirisinghe, Nawawi, 2002). In terms of the effect of coconut water on exercise in the US, very few peer reviewed research studies have been completed (Saat et al, 2002).

The body requires inorganic ions to perform normal cellular function, enzyme activation, bone formation, hemoglobin function, gene expression, and metabolism of amino acids, lipids,
and CHO (Yong, Ge, Fei Ng, & Ngin Tan, 2009). A list of inorganic ions commonly found in coconut water can be found in Table 8.0 in the Discussion chapter of the text. The amount of micronutrients found in coconut water may vary depending on species of coconut and maturity of the coconut (Kalman et al., 2012). The composition of coconut water can replenish electrolytes lost through sweat such as potassium, sodium, magnesium and calcium leading to an affective rehydration drink (Brooks et al., 2005, McArdle et al., 2007; Kalman et al., 2012; Yong et al., 2009). Ions are important because chloride is known as essential for fluid balance in the body; sodium and potassium are needed for muscles and nerves to work properly; and calcium helps muscles and blood vessels contract and expand (Brooks et al., 2005).

Coconut water is also composed of many vitamins as can be seen in Table 2 above. One vitamin contained in coconut water is vitamin B6, a water-soluble vitamin required as a co-enzyme for enzymatic activity. B6 is the co-enzyme of γ-cystathionase, which catalyses the cleavage of cystathionine which in turn releases α-ketobutyrate and cysteine. The α-ketobutyrate converts into succinyl-CoA, an intermediate of the TCA cycle (Yong et al., 2009). B6 infusion also increases plasma growth hormone which may play a role in hypertrophy for strength athletes while it has been a suggestion that PAK, a combination of B6 and α-ketoglutarate, be used as an ergogenic aid due to the ability to lower lactate levels (Brooks et al., 2005).

Coconut water does contain sugar (carbohydrates) which provides energy. There is a fair amount of research looking at CHO effects on rehydration and exercise recovery (Kalman et al, 2012; Currell & Jeukendrup, 2008; Jeukendrup, 2004; Hulston & Jeukendrup, 2009; Wong et al, 2009). Many researchers have shown some benefit in performance with a CHO beverage
supplement (Currell & Jeukendrup, 2008; Hulston & Jeukendrup, 2009). Increased performance was measured in a controlled environment where subjects were asked to either run or cycle for a prolonged period such as 1-2 hours and given a supplement, beverage, or plaGo at set intervals. The prolonged exercise period allowed the glycogen energy stores to be depleted or at least significantly lowered (Kalman et al, 2012; Hulston & Jeukendrup, 2009; Wong et al, 2009). Then the subjects were asked to complete a run or cycle at maximum effort, typically for as long and as fast as they can while performance measurements such as power output and time sustained can be taken and analyzed depending on the ingested CHO supplement (if any). There have been various beverages tested in this way and studies could be easily modified to include coconut water (Currell & Jeukendrup, 2008; Wong & Chen, 2011; Hulston & Jeukendrup, 2009; Wong, Chan, Chen, Hu, Lam, & Chung, 2009).

Coconut water companies use the electrolyte content as a selling point for their product. Coconut water contains all 5 essential electrolytes - sodium, potassium, chloride, calcium, and magnesium (Coco5 website 2012; Ismail, Singh, & Sirisinghe, 2007; Yin, 2010; Saat et al, 2002; Kalman et al, 2012) and sometimes is called “Mother Nature’s sports drink” for its more natural properties (Zelman, 2010). In contrast, most common carbohydrate electrolyte (CE) beverages such as “Gatorade” contain sodium, potassium, and chloride but not normally calcium or magnesium. As can be seen in Table 1, CB typically has far more electrolytes then the leading CE.

Athletes need to perform their best so they are seeking products which may help them train harder and longer as well as recover faster. Research would help validate or confirm claims
about coconut beverages (CB) and allow consumers to understand better how a CB will enhance their training sessions. The effect CB has on both glucose and lactate production and/or clearance can better justify the use of CB with high-level athletes.
REFERENCES


