Submaximal Exercise Performance In Fasted vs. Non-Fasted Individuals

This project makes no effort to suggest generalizability. Instead, it was designed to demonstrate competency using lab equipment, capacity to integrate knowledge with application, and understanding of the scientific method.

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Introduction

Substrate utilization during exercise depends greatly upon the intensity and duration of the exercise. Although all carbohydrates, fats, and proteins are utilized to some extent during all physical activity, intensity and duration control which substrate the body prefers over the others (Haff & Triplett, 2016). During short duration, high power exercise, carbohydrates are the preferred energy source because catabolism does not require various steps. Carbohydrates are the only fuel source that does not require oxygen for catabolism, therefore it is the most useful when a quick supply of energy is needed (Haff & Triplett, 2016). According to the Kanter (2017), carbohydrates are an essential energy source during high intensity exercise. During long duration, steady state exercise, fats are utilized at a higher rate than other substrates (McArdle, Katch, F., Katch, V., 2015).

Fats are stored at higher amounts in the body and take longer to catabolize than carbohydrates, which is why they are preferred during exercise with lower intensity and higher duration (Haff & Triplett, 2016). Proper nutrition or body composition are factors which can affect the bioavailability of substrates during physical activity (Haff & Triplett, 2016). According to Whitley & colleagues (1998), consuming a meal prior to exercise can affect substrate availability in the blood plasma. Generally, a pre-exercise meal supplies the macronutrients which affect which substrates are more readily available and how they will be utilized during physical activity. For example, consuming a high carbohydrate meal prior to exercise spares glycogen stores in the muscle (McArdle et al., 2015). According to Burke and colleagues (2017), consuming a low-carbohydrate, high-fat meal negatively impacts exercise performance and intended benefits of exercise at higher intensities. Athletes required to sprint, swim, or perform in short bouts for sports such as football or basketball, consuming a high carbohydrate meal would be more beneficial (Haff & Triplett, 2016).

Identifying which substrate the body is mostly utilizing during physical activity can be found using the respiratory exchange ratio, RER. This value is indicative of whether carbohydrates or fats are the primary energy source of specific exercise modes. An RER value between 0.70 and 1.00 indicates that carbohydrates are the primary energy source (McArdle et al., 2015). Due to pre-exercise meal consumption altering the bioavailability and utilization of certain substrates, fasting prior to exercise could have alternative affects on substrate utilization, or RER. This study seeks to understand the possible differences in substrate utilization that may occur when the body is in different physiological states. The purpose of this study is to compare exercise performance and substrate utilization in fasted and non-fasted, healthy college students during submaximal exercise on the leg ergometer. It was hypothesized that consuming a meal prior to submaximal exercise will yield a higher RER value compared to fasting at least three hours prior to the start of exercise.

Methods

There will need to be multiple subjects for this experiment. Two subjects are young, healthy men and two subjects are young and healthy women. One man and one woman should eat a meal three hours prior to the test. The remaining subjects are required to fast for three hours prior to the test. The heart rate, RPE, oxygen consumption and blood pressure will be monitored to insure the safety of the subjects, however the RER, and VE will be the main variables collected during the test. The independent variable is carbohydrate consumption while the dependent variables are the RER and VE.

The equipment required for this test is the ergometer bike, the rudolph mask, pulse oximeter, the metabolic cart, RPE chart and the blood pressure cuff. The vitals being taken are the blood pressure, heart rate, oxygen consumption, ventilation and the respiratory exchange ratio. The first step to complete the lab is to turn on the metabolic carts 30 minutes prior to testing. Then the metabolic carts need to be calibrated under the exercise metabolism setting. The equipment then needs to be set up with the subject hooked up to the metabolic cart. Then the testers will create a heart rate map based on their maximum heart rate (208-.7*age). If the subject reaches above 85% of their maximum heart rate then the test will be terminated. Have the subject maintain a RPM of 70; This will need to be monitored throughout the entirety of the test. Establish the RPE chart and monitor every change in intensity. The oxygen percentage needs to be 16% while the carbon dioxide is 4% before the test can begin.

The test will begin with the subject resting for two minutes, at the end of the two minutes the vitals should be taken. Then the subject will begin a 5 minute warm up at 0 resistance, at the end of the warm up the vitals should be collected again. After the warm up the subject will begin to test with an increasing difficulty. At the end of every 5 minute stage increase the resistance by 25 W and have the data collected. Follow the table below as a guide for the testing stages and data collection timing. If at any point the heart rate is too low for the difficulty, increase the resistance another 25W to allow for the heart rate to reach the percentage of the maximum. This should be checked and adjusted every two minutes in each phase of the test outside of the warm up and resting periods. At the conclusion of the heavy intensity stage, the subject will sit and rest for 5 minutes before the vitals are taken again. The the subject is unhooked from the equipment and free to leave. The testers will then clean up the station.

Intensity	Wattage	Time	Data Start	Data Collection
Rest	Rest	0:00-2:00	1:30	2:00
Warm Up	Rest	2:00-7:00	6:30	7:00
Light (50% MHR)	25 W INC	7:00-12:00	11:30	12:00
Moderate (60% MHR)	25 W INC	12:00-17:00	16:30	17:00
Heavy (70% MHR)	25 W INC	17:00-22:00	21:30	22:00
Rest	Rest	22:00-25:00	24:30	25:00

Results

Table 1 depicts the RER and VE for all of the subjects. For the two subjects that had fasted, the RER is lower. The VE is also slightly lower for the subjects who had fasted. The correlation values between the RER and VE for all of the subjects range from r= 0.82 to r= 0.98. This means that the correlation is direct and strong. The standard deviation of the subjects RER ranges from 0.06 to 0.19, meaning the subjects RER fluctuated a decent amount but not too drastic. The standard deviation for ventilation ranges from 5.5L/br to 8.45L/br. This suggests that the subjects had differences in the subject's pulmonary health.

Table 1

The mean, standard deviation and range for the respiratory exchange ratio (RER) and ventilation (VE) (L/br) of the fed female, fasted female, fed male and fasted male as well as the correlation value between the RER and VE for each of the subjects.

Variables	Fed Female	Fasted Female	Fed Male	Fasted Male
Mean (RER)	0.98	0.88	0.97	0.89
Standard Deviation (RER)	0.19	0.06	0.11	0.12
Range (RER)	0.78	0.30	0.42	.0.58
Mean (VE)	21.8	20.4	22.5	18.7
Standard Deviation (VE)	8.45	5.5	7.1	6.1
Range (VE)	33.5	23.7	33.3	23.8
Correlation Value(RER/VE)	0.97	0.97	0.82	0.98

Figure 1 depicts the RER for fed female subject began at a lower rate and gradually increased over the exercise session. RER for fasted female began at a slightly higher rate, the RER then fluctuated and slowly increased throughout the test. The RER for the fed male subject periodically rose and fell until fifteen minutes of exercise and then gradually increased until resting period. RER for fasted male subject gradually increased until eighteen minutes, then increased slightly before decreasing during the resting period.

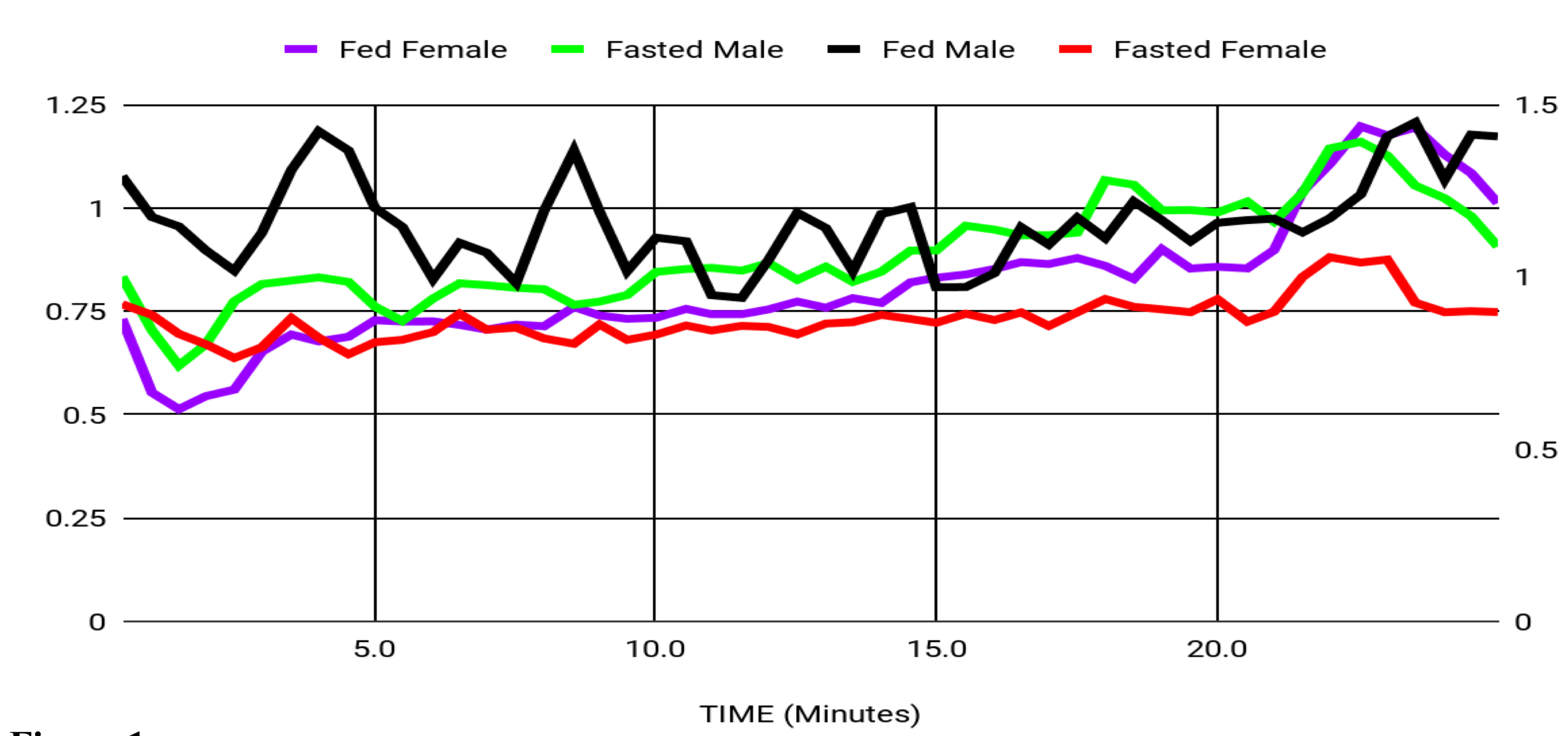

Figure 1. *The RER of fasting females and males as well as non-fasting females and males over the duration of the submaximal bike test.*

Table 2 depicts the fluctuation of the RER amongst the different subjects over the duration of the submaximal bike test. The RER of the fed female fluctuates and then increases at 15 minutes. The RER for the fasted female had a more steady increase and did not fluctuate. The RER for the fasted male did not fluctuate as intensely as the fed male.

Table 2

RER for fasted females and males and RER for females and males who ate prior to testing over the duration of the test

Time (Min)	Fed Female	Fasted Female	Fed Male	Fasted Male
0:00	0.88	0.92	1.08	0.83
5:00	0.87	0.81	1.00	0.76
10:00	0.88	0.83	0.93	0.85
15:00	1.00	0.87	0.81	0.90
20:00	1.03	0.93	0.96	0.99
25:00	1.21	0.90	1.17	0.91

Discussion

The normative values of the respiratory exchange ratio (RER) for young, healthy adults at rest and at moderate exercise are between 0.7 and 1.00 (McArdle, Katch & Katch, 2015). The fed male subject achieved the mean RER of 0.97. The fasted male had the RER value of 0.89. The fed female had an RER value of 0.98 and the fasted female had the RER of 0.88. The observation that those who fasted reached a lower RER than those who were fed suggests that the RER and carbohydrate consumption are related. The physiology behind this is that carbohydrates are easier to metabolize because they don't require as much time in the process to create energy (Haff & Triplett, 2016). This means that the body will begin to metabolize carbohydrates rather than fats (McArdle, Katch & Katch, 2015). Due to the increased requirement of carbohydrates in aerobic metabolism, the RER will increase. The basic and most popular carbohydrate is glucose ($C_6H_{12}O_6$) which is the source of most of the aerobic energy (McArdle & Katch, 2015). This is necessary information because the process of metabolism takes one glucose compound and 6 O_2 compounds and converts it to carbon dioxide, water and energy (McArdle, Katch & Katch, 2015). Energy and water are utilized throughout the body and the carbon dioxide is typically expelled (McArdle, Katch & Katch, 2015). According to Bergman and Brooks (1999) the RER is also considered the same as the non-protein respiratory quotient (RQ).

According to McArdle, Katch and Katch (2015) the equation for non-protein RQ is carbon dioxide produced divided by oxygen consumed. Due to the non-protein RQ and RER being the same, the non-protein RQ equation can be used to calculate the RER based on carbohydrates. The higher the RER is, the more carbon dioxide is being produced compared to the oxygen being consumed (McArdle, Katch & Katch, 2015). When the oxygen and carbon dioxide are approximately the same, the RER is 1.00 (McArdle, Katch & Katch, 2015).

The ventilation (VE) normative value is 6L/br for resting individuals and for light intensity, the value is 75 L/br (McArdle, Katch & Katch, 2015). The fasted male achieved the average VE of 18.7 L/br. The fasted female had the average VE of 20.4 L/br. The fed male had the average VE of 22.5L/br and the female had 21.8L/br. Ventilation is calculated by multiplying tidal volume and breathing rate together (McArdle, Katch & Katch, 2015). According to McArdle, Katch and Katch (2015) the tidal volume is defined as the amount of air inspired and expired per breath. The breathing rate is defined as the amount breaths taken in one minute (Beam & Adams, 2014). Increased ventilation is due to the need for oxygen consumption to increase in order to keep up with the metabolic demands. This means the RER and exercise ventilation are correlated. The correlation values for the RER and VE are r= 0.97 (fed female), r= 0.97 (fasted female), r= 0.82 (fed male) and r= 0.98 (fasted male). All of the correlation values are strong direct correlations, this means that they are related to each other. This is because the ventilation has an oxygen consumption and carbon dioxide expelion in the tidal volume. The faster the subject breathes, the more CO2 and O2 is being exchanged (McArdle, Katch & Katch, 2015). This is critical because ventilation increases as the duration increases because the body requires more carbohydrate metabolism for faster energy metabolism to keep up with the energy demand.

According to the current literature, the RER should demonstrate the lipid crossover during the submaximal bike test. The exercise ventilation should also increase as the lipid crossover occurs. The fed subjects did experience this a minor amount due to their ability to reach the higher carbohydrate utilization earlier in the exercise because they had carbohydrates available in their system for metabolism. The fasted subject did not reach the lipid crossover due to there not being a supply of carbohydrates in their system to utilize. These are results that correspond with the literature. The possible errors that could cause less variation in the results between the fasted and fed individuals is if the individuals had exercised within 12 hours prior to testing. If they did, their oxygen consumption could have already been higher because they had a higher EPOC than someone who had not exercised (McArdle, Katch & Katch, 2015). Another issue that could be a factor that reduced the variation was that the test wasn't intense enough to achieve the lipid crossover. The lipid crossover occurs at a specific part of aerobic power, this occurs usually around 60% of the aerobic power (Brooks, 1998). This means that it possible the test was too easy for the subjects to reach the true lipid crossover.

Monitoring the RER is also important because it helps monitor the energy expenditure and requirement of the subject (McArdle, Katch & Katch, 2015). This can help make sure that the subject is healthy and able to perform at intense levels. Another important value to monitor for the subjects safety in a training environment is their ventilation. By monitoring the subjects ventilation, it can be seen that subject has healthy lungs and that they move air properly. This is another important safety variable in training because if the subject has too low or too high of a ventilation, the subject risks passing out and getting hurt (McArdle, Katch & Katch, 2015). This information can be applied in training environments by the need to increase the subject's carbohydrate consumption prior to their performance. In aerobic activities, it is important the subject consumes a higher carbohydrate meal so they are able to achieve the lipid crossover earlier. If this is done, the subject will have most likely reached the steady state exercise and they could theoretically perform at that specific pace forever (McArdle, Katch & Katch, 2015).

Conclusion

The result of this study indicates that consuming a meal higher in carbohydrates before performing a submaximal test allows for carbohydrates to become the predominant fuel source. As compared to fasting, the predominant fuel source is a mixtures of fat and carbohydrates. Consuming carbohydrates before performing submaximal exercise allows a higher energy output which allows for a greater performance. This test allows the measurement of the respiratory exchange ratio of an individual to be monitored. This is helpful in assessing individuals and their nutritional needs when performing exercise. To further increase the validity of this test more subjects should be tested. Along with more subjects the amount of time the subjects were fasted should be increased.

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