Courtney Buchanan

Thermic Effects of Food and Exercise; Are They Symbiotic?

Kinesiology and Integrative Physiology

Professor Stamford

Winter Term 2018

Abstract

Objective: This study investigated the combined impact of the thermic effect of food and the thermic effect of exercise while varying meal size prior to exercise and also varying the intensity of exercise. The symbiotic relationship between the TEF and TEE was examined during the study. This means TEF and TEE influenced each other resulting in and increased effect. It was hypothesized that the symbiotic relationship would be present and that a large meal would have a greater effect on metabolic rate when compared to small meal.

Methods: Two Hanover College female students participated and a total of four trials were conducted. The first trial was an orientation trial in which the two workloads of light (120-125bpm) and moderate (135-140bpm) were found. The second trial was a fasted trial not combining the TEF and TEE. The third and fourth trial combined the TEF and TEE, looking at the effects of a small versus large meal. The small meal was composed of 400 kcals and the large meal was composed of 800 kcals. The three trials were composed of walking at a light and moderate intensity for 10 minutes and then an after burn stage for 10 minutes.

Results and Discussion: The light intensity trial for a small meal showed a 1.1% increase while the large meal had an 7.6% increase in energy expenditure when both were compared to the fasted trial. The moderate intensity exercise for a small meal showed a 3.8% decrease in energy expenditure when compared to the fasted trial. The large meal for moderate intensity there was a 4.7% increase when compared to the fasted trial. The after burn period consisted of standing at rest for 10 minutes on the treadmill while being hooked up to the parvo medics cart. The small meal had an 1.6% increase in energy expenditure while the large meal had a 10.4% increase when both were compared to the fasted trial. All the hypotheses were accepted and reasoning can be explained by the sympathetic nervous system mechanism. The sympathetic nervous system (SNS) is turned on during both exercise and digestion, but what happens when these two processes of the TEF and TEE are occurring together rather than separately? This can be the answer as to why there is a bonus burn of calories, which is due to the over stimulation of the SNS since both processes TEF and TEE are turning it on. Which supports that there is a symbiotic relationship between the TEF and TEE.

Table of Contents

Chapter One

Chapter Two

Chapter Three

Chapter Four

Chapter Five

References

Chapter One

Introduction

The term metabolism covers numerous processes needed to sustain the human body and to keep it functioning properly. Metabolism is driven by three factors; basal metabolism, the thermic effect of food and the thermic effect of exercise. Basal metabolism encompasses the energy expenditure needed at rest to keep the body functioning properly (12). Basal metabolism is a highly active and on-going process within the human body. The thermic effect of food (TEF) is defined as the increase in energy expenditure after consuming food (14). The TEF requires energy for processes such as digestion, absorption and storage of nutrients (4). The third factor is the thermic effect of exercise (TEE), which is the energy needed for skeletal muscle contractions (3).

Basal metabolism is important, but the focus throughout this study is on the TEF and the TEE. Research has supported a symbiotic relationship between the TEF and TEE, but other studies refute this relationship (9). The term symbiotic can be defined as two components being mutually beneficial to each other. In operational terms for this study the symbiotic relationship suggests that the coupled effects of the TEF and TEE increase caloric expenditure more than if the two processes occurred separately. The increase in caloric expenditure is what is known as the "bonus burn" of calories. The symbiotic relationship will be investigated throughout this study, while examining how altering different factors within the relationship can have an outcome on energy expenditure.

There are many factors that can contribute to a change in results associated with the relationship between the TEF and TEE. Factors such as meal composition, exercise intensity, gender, age, etc. can all have an impact on results (10). Other possible factors that could modify the symbiotic relationship include work capacity and meal size (6). Studies have examined the effects of altering different factors. This study will examine the effects of altering two factors, exercise intensity and meal size (kcals).

Statement of the Problem

To investigate the combined impact of the thermic effect of food (TEF) and the thermic effect of exercise (TEE) on metabolic response.

Significance of the Study

Personal Significance

This topic has been an area of interest since last year when the idea of a symbiotic relationship between the TEF and TEE arose in class. I wanted to investigate this relationship further and see if meal size and/or exercise intensity would have an effect on metabolic rate. I have found research to support that there is a symbiotic relationship between the TEF and TEE, but have found research to refute it. I want to confirm that there is a symbiotic relationship, while also looking at what happens if components that affect the TEF and TEE are altered.

This study will also be significant personally if there proves to be a "bonus burn" of calories when coupling the TEF and TEE. I enjoy eating, walking and burning calories and being

able to do all three is an appealing combination. If all I had to do was switch the time of my walk to get a "bonus burn" of calories, I would definitely do so. For individuals not wanting a gym membership, walking after a meal could be a good alternative for low to moderate intensity cardio. It would be non-expensive and could be performed in most places in any clothing attire, which is suitable for the average person.

In general, the public does not know about the relationship between the TEF and TEE. The results from this study could be provide important and useful information that could aide in weight loss and overall a healthier lifestyle. I hope that the results will provide information to show a relationship between the TEF and TEE and see how altering different factors affects the symbiotic relationship.

Scientific Significance

The Center for Disease Control and Prevention reported that 70% of adults aged 20 and over to be overweight and/or obese in 2016 (11). On average most people are not following a heart healthy diet, along with not getting the appropriate amount of exercise. The average lifestyle is contributing to the increasingly high statistics that are associated with obesity. This study could potentially provide information that can increase caloric expenditure by altering the time and content of their meal. Duration, frequency and intensity guidelines have been set for exercise, but the suggestion for the optimal time after a meal has not. This study will examine meal size and how time in relation to the meal can be useful for receiving additive effects. While the caloric expenditure might not be a significant amount, overtime it can be an effective weight management tool.

Delimitations

1. Number of subjects:
    a. 2
2. Age range of subjects:
    a. 21-22 yrs. old
3. Gender of subjects:
    a. Female
4. Number of trials:
    a. 4
    b. Orientation
        i. Familiarize subject with the testing process and equipment
        ii. Record height, weight and resting heart rate
        iii. Subject perform on treadmill (4-hour minimum fast) to determine steady state heart rates for desired intensities
    c. Control
        i. Subject performed testing while being in a fasted state (4-hour minimum fast)
    d. Small meal
        i. Subject performed testing 35 minutes after consuming a small meal (~400 kcals)
        ii. 4-hour minimum fast is required

    e. Large meal
        i. Subject performed testing 35 minutes after consuming a large meal (~800 kcal)
        ii. 4-hour minimum fast is required
    f. Trials c and d were performed in a randomized order
5. Independent variables:
    a. Meal size
        i. Small
        ii. Large
    b. Exercise intensity
        i. Light
        ii. Moderate
6. Dependent variables:
    a. Heart rate
        i. Measured in: bpm
    b. Metabolic rate
        i. Measured in: kcal/min
7. Control variables
    a. No physical activity prior to testing
    b. No caffeine 24 hours' prior
    c. Fasted 4-hour minimum
    d. 45-minute window to consume meal
    e. Testing occurs at the same time of the day
    f. Testing occurs on the same days
    g. Meals and meal content was the same for all subjects according to given trial
8. Measurements to be taken:
    a. Heart rate
    b. Metabolic rate
9. Equipment:
    a. Treadmill
    b. Polar heart rate monitor
    c. Metabolic cart
10. Type of training:
    a. Walking on a treadmill
11. Training intensities:
    a. Light
    b. Moderate
12. Duration of training:
    a. 25 minutes of exercise
13. Duration of study:
    a. 1 week
14. Analytical procedures:
    a. Comparing mean and standard deviation values

Limitations

There were only two subjects who were tested and they were both females between the age of 19-21. Metabolic response can be altered by many factors such as gender, age, body composition and illness. Only females between the age of 19-21 were tested, so it was a restriction of both gender and age. There were only two subjects chosen because of the time limit for the project.

This study examines the outcomes on heart rate and metabolic rate when altering calorie consumption and exercise intensity during a workout. There were only two variables being examined, but there are more variables that could be added to the study that could augment for additional research. Examples for future studies include; comparing different age groups of women, comparing between genders or looking at individuals with different body compositions. Another idea for a potential study would involve alternating of the macronutrients (carbohydrates, fats and proteins) within the meal and comparing if the meal composition alters heart rate and/or metabolic more or less.

Assumptions

a. The calories for each meal were similar
b. The macro nutrients for each meal was similar
c. The Polar Heart Rate monitor was a reliable tool for measuring the heart rate
d. The Parvo Medics cart was reliable device for measuring metabolic rate
e. There was a minimum of at least a 4 hour fast when performing all trials
f. The investigator was valid when recording height, weight, resting heart rate and blood pressure measurements
g. The thermic effect of food was in effect after 30 minutes of food consumption
h. The determined workload was suitable for that intensity range
i. No caffeine was consumed prior to any of the experiment trials

Hypotheses

It was hypothesized that during exercise…

1. The small meal will increase metabolic rate
2. The large meal will increase metabolic rate
3. The large meal will increase metabolic rate more than the small meal
4. The impact of a meal combined with moderate intensity exercise will be greater than the impact of a meal combined with light intensity exercise

Definition of Terms

1) Basal Metabolism: energy expenditure needed to keep the body alive

2) Thermic Effect of Food (TEF): energy expenditure needed to digest and absorb food

3) Thermic Effect of Exercise (TEE): energy expenditure needed for muscular activity

4) Thermogenesis: production of heat within the body

5) Post absorptive: time after nutrients have been absorbed

6) Postprandial: post food consumption

7) Symbiotic relationship: the sum of the outcome of two processes occurring separately is smaller than the sum when two processes occur together

8) Parvo Medics Cart: apparatus that is used to measure oxygen consumption while performing exercise that calculates energy expenditure

9) Indirect Calorimetry: method used to measure oxygen consumption and carbon dioxide production that leads to the calculated energy expenditure for the period of the workout

10) Metabolic Rate: overall rate in which chemical reactions occur in the body

11) Basal Metabolic Rate (BMR): amount of energy expended at rest under strict conditions

12) Resting Metabolic Rate (RMR): amount of energy expended at rest under less restrictive conditions than BMR

13) Exercise Post Oxygen Consumption (EPOC): elevation in metabolism post exercise

Chapter Two

Background

Metabolism

Metabolism is influenced by energy turnover, which includes the relationship between nutrition and exercise (5). Energy is provided through consuming nutritious foods and energy is required for daily activities including exercise. Energy is needed to sustain vital metabolic functions at rest, under thermo-neutral and post-absorptive conditions (12). Energy needed to maintain the basic functions of life can be termed as basal metabolic rate (BMR) (12). Energy expenditure in BMR include processes like protein and lipid synthesis, muscular activity for cardiac and respiratory activities (12). BMR is difficult to measure due to the restrictive conditions under which it is measured (12).

Since BMR is difficult to measure, resting metabolic rate (RMR) is more commonly used. Resting metabolic rate is a less restrictive way of measuring the energy needed to sustain the body at rest. Indirect and direct calorimetry are both ways of measuring energy expenditure under different conditions (12). Direct calorimetry is more extensive and expensive; therefore, indirect calorimetry is the preferred method.

Metabolism is composed of three factors; basal metabolism, thermic effect of food (TEF), thermic effect of exercise (TEE). Basal metabolism was discussed in the previous paragraph and the TEF and TEE will be discussed later in the paper. Although basal metabolism requires the most energy (~70%) out of the three factors, the focus for this experiment is on the TEF and TEE.

Summary:

Metabolism is a highly active process that includes both the consumption and expenditure of energy. It is composed of three factors; basal metabolism, TEF and TEE. Basal metabolism is the bare minimum of energy required to sustain the body and its processes at rest. Basal metabolism is the factor that requires the largest amount of energy. The focus for this experiment is on the TEF and TEE.

Thermogenesis

Thermogenesis can be termed as the production of heat within the human body (12). It is a critical process in the body and accompanies all of the metabolic processes that are needed for sustaining life (7). Thermogenesis encompasses the energy expenditure needed for the thermic effect of food (7). Most energy for body processes is derived from the three macronutrients; carbohydrates, fats and protein (12). Energy comes from carbohydrates, fats and protein and energy can also be conserved in the bonds of adenosine triphosphate (ATP) (12). When energy is needed this stored energy can be hydrolyzed to provided energy for cellular processes (12). This conversion of energy is not 100% efficient and most of the energy is dissipated as heat (12). It is stated that the energy for a system is supposed to stay constant. This statement related to the first law of thermodynamics, which states that energy cannot be

created nor destroyed, but can be transferred. This experiment will be looking at how energy is being transferred during different stages.

Summary:

Thermogenesis is defined as heat production within the body and encompasses processes such as the TEF. The TEF requires energy, which comes from food derived from the three macronutrients. The energy needed for the TEF has to be transferred to a usable form, which is not a 100% efficient processes. The first law of thermodynamics is relevant in this process.

Thermic Effect of Food

Once food is ingested there is an increase in energy expenditure, which is referred to as the thermic effect of food (13). Energy expenditure in the human body is reliant upon the thermic effect of food and plays an important role (4). Energy expenditure making up the thermic effect of food requires energy for ingesting, digesting and processing food (7). Once food is consumed it causes and increase in metabolic rate and this can occur for hours afterwards (12). The increase in metabolic rate can vary due to the dependency of many factors (12). Nutritional content and the caloric load of the meal consumed can both be factors that alter metabolic rate (12).

Focusing in on one factor in specific is looking at the difference in metabolic rate when altering the size of a meal. A larger meal has shown there to be a greater effect on the thermic effect of food (12). The increase in metabolic rate can be linked to the challenge placed on the system to process a large meal. The contents of the meal will also play a role in metabolic rate. Looking at the three macronutrients, protein has the highest rate of energy expenditure, due to its high energy cost (12). Studies have shown that the oxygen consumption was greater for a protein meal then the other macronutrients (8). It is recommended for individuals to consume high protein diets if they are looking to lose weight, due to proteins high specific dynamic action (2). The increase in postprandial metabolic rate is what is referred as to the specific dynamic action (2). The TEF effect ranges from 4-8 hours post meal, but the increase in caloric expenditure peak time varies (8). Other factors that influence the TEF include previous diet, physical activity, insulin resistance and ageing (8). But this study is focusing in on the factor of differences in meal size.

Summary:

The rise in energy expenditure once a meal is consumed is what is termed as the thermic effect of food (TEF). Energy for the TEF is required for processing and digesting the food consumed. The energy needed for this process can vary due to different factors that can alter energy requirements. Factors that can alter metabolic rate include meal size, meal composition, previous diet, body composition and ageing. Meal size has shown significance in other studies and this is what the focus of this experiment is on.

Thermic Effect of Exercise

Regular exercise is a tool that is suggested to ease the burden of diseases that are affecting numerous amounts of people today (5). Guidelines for exercise intensity, duration and

frequency have been set, but the optimal timing in relation to a meal has not been set (5). A sedentary lifestyle gives rise to diseases such as cardiovascular disease, obesity and metabolic syndrome (5). The increase in disease could possibly be related to the decrease in physical activity. Knowing when the best timing for exercise is can be a motive for individuals to exercise and to obtain additive benefits.

Exercise type can largely vary and calorie expenditure for each type varies as well. Caloric cost of the same activity can range for different individuals based upon factors such as age, sex and body weight (14). Another factor that can alter calorie expenditure is the intensity of the exercise. The higher the exercise intensity the more blood flow required to feed the working muscles (4). The sympathetic nervous system (SNS) is stimulated by exercise (8). Variations in the degree of stimulation can be related to factors such as intensity and duration of the exercise (8). Other factors that can alter the TEE include time between the meal and exercise and previous exercise (8).

Summary:

While guidelines for exercise duration, intensity and frequency have been set, an important point of optimal timing in relation to a meal has not been set. Knowing when the optimal timing for exercise is in relation to a meal can be a motive in increasing a more active lifestyle. A more active lifestyle can in return reduce the risk of disease and other burdens. Different factors can affect the outcomes on the TEE, such as exercise intensity, duration and body composition. The SNS is affected during exercise and can be stimulated more with higher intensity exercise.

Symbiotic Relationship

As stated earlier both the TEF and TEE require energy when they occur separately. Research has shown that physical activity after meal consumption can potentiate the TEF (4). While other studies have shown there not to be a symbiotic relationship or one to be that great (4). The symbiotic relationship between the TEF and TEE can near double the caloric response in lean subjects (4). These two processes come together with the stimulation of the sympathetic nervous system (8). The additive effects of TEE and TEF caused an increase in different factors such as caloric expenditure (1).

Knowing that the TEF and TEE can work together in creating additive benefits for individuals it is important to know when is the optimal timing for their relationship. Finding the optimal time to exercise in relation to a meal can increase the benefits of the outcome of the same amounts of exercise just at different times (5). This could be particularly important for individuals who need these additional benefits that cannot increase the duration or intensity of exercise (5).

Summary:

Research for the symbiotic relationship between the TEF and TEE has been debatable on whether it exists or not. Research accepting this relationship can also vary on the outcome with altering different factors. The two processes stimulate the SNS, which increases both heart rate and metabolic rate more when the two processes occur together than when they occur

separately. Knowing their symbiotic relationship and optimal timing is potentially very beneficial for individuals need additional health benefits.

Overall Summary:

Metabolism covers a multitude of processes that occur daily within the body. All metabolic processes require energy to perform properly. Metabolism and the factors that go into it can be altered. For example, different individuals have different metabolisms and different metabolic rates. Why does it vary person to person? Well factors such as age, gender, body composition and other factors can alter metabolism and the metabolic rate. Other factors that can vary the daily energy expenditure for a person include factors such as diet, daily activity, exercise intensity and relation of a meal with exercise. The body requires different amounts of energy under different conditions on a daily basis.

Energy within the body can be stored and/or used, but to get one from or the other energy must be transferred. For example, when food is consumed it goes through different processes to be transferred into a usable form by the body. When energy is used the process is not 100% efficient and some of the energy is lost as heat. Heat generation in the body is defined in scientific terms as thermogenesis. The first law of thermodynamics states that energy can be transferred, but neither created nor destroyed. This law is necessary during the thermogenic process when it occurs in the human body.

An energy balance in the body is necessary to ensure overall health. Receiving energy from food is crucial and occurs every day. Expending energy in the form of exercise or other physical activity and is recommended for a healthy lifestyle. The body expends energy in three different processes. When the body is at rest energy is expended to keep the body functioning properly so that it stays alive, which is known as basal metabolism. A step up from basal metabolism is the thermic effect of food (TEF), which takes into consideration the energy needed to digest, store and use nutrients from foods that are consumed. The third factor of energy expenditure is what is known as the thermic effect of exercise (TEE), which encompasses the energy needed for muscular activity. All three of the factors together are what make up overall metabolism.

There is still controversy over the symbiotic relationship between the thermic effect of food and exercise. Studies have shown there to be a relationship while others have shown no evidence of a symbiotic relationship. Factors can go into altering the symbiotic relationship such as exercise intensity and meal size, which this study will be examining. Other factors can alter the symbiotic relationship such as meal composition, type of exercise and characteristics of the subject. A future study could be examining if altering macro nutrient content has a significance on the symbiotic relationship outcome. This study will provide information that will either support or refute the idea of a symbiotic relationship.

Whether there is or is not a symbiotic relationship other health benefits can come from combining the TEF and TEE. Studies show that the effects of combining the two can help with digestion and other health benefits. The information from this study can provide insight for the public in understanding the symbiotic relationship between the TEF and TEE. If this relationship is shown to be true, then other valuable information such as the health benefits and other additive effects can be used to increase the overall health of the general public.

Review of Related Literature

1) Kinabo, J. L., and J. V. G. A. Durnin. "Thermic Effect of Food in Man: Effect of Meal Composition, and Energy Content." British Journal of Nutrition 64.01 (1990): 37. Web.

- Supports hypotheses 1,2 and 3
  It was hypothesized that during exercise…
  - 1. The small meal will increase metabolic rate
  - 2. The large meal will increase metabolic rate
  - 3. The large meal will increase metabolic rate more than the small meal
- Provided useful sources
  - Refuting meal size
  - Supporting meal size
  - Protein content

The purpose of this study was to determine if meal composition or energy content was more significant in the TEF. The study examined 16 adult non-obese females. Testing included a total of four meals being consumed on different days. The meals were composed of high-carbohydrate (HCLF) and low-carbohydrate-high-fat (LCHF). The energy content for each composition was 2520 kJ (600 kcal) and 5040 kJ (1,200 kcal). This study used indirect calorimetry to measure basal metabolic rate (BMR) and postprandial metabolic rate (PP-MR).

Pre-test protocol included no food or drink prior to testing and to journal food and drink consumption on the prior day. Abstaining from caffeine was a strict pre-test protocol, as it would alter the results. The meal for this study was not in the form of the blend, instead it was regular food items you would consume during a daily meal.

The results from this study showed that the energy content of a meal has a significance on the TEF, while the meal composition does not. The results that show meal size does have a significance, which supports hypotheses 1 and 2. Then the results that showed the larger meal having a greater effect on the TEF and energy expenditure supports hypothesis 3.

This article listed other research studies that were useful. It provided sources that refuted meal size having an influence on the TEF and provided references that supported this concept. The article also went into detail about protein content in a meal and how it is the most thermogenic nutrient. The researcher used the information about protein and its thermogenic content when making the meal for the study. The researcher had chosen foods that were high in protein content, so that there would be a greater thermogenic response.

2) Kang J, et al. “Metabolic Responses during Postprandial Exercise.” Research in Sports Medicine (Print), vol. 21, no. 3, 2013, pp. 240–52., doi:10.1080/15438627.2013.792088.

- Supports hypotheses 4 and 5

It was hypothesized that during exercise…
- 4. The small meal will increase heart rate
- 5. The large meal will increase heart rate

- Provided information in support of hypothesis 6
  - 6. The large meal will increase heart rate more than the small meal
- Supports that there is a symbiotic relationship between the TEF and TEE

The purpose of this study was to "examine metabolic interaction between meal and exercise". As the title states there were three trials of (1) exercise only, (2) consumption of a meal (no exercise), and (3) consumption of meal followed by exercise. The trials were completed by 10 healthy and untrained men and women. The trials were completed at random and were separated by at least 2 days. The meal consumed during the experiment was composed of 41%, 36% and 23% carbohydrates, lipids and protein which totaled to be 721 kilocalories.

Pretest protocol included no vigorous activity prior to testing along with no alcohol or caffeine. Other pretest protocol was to follow a dietary guideline prior to testing, which was given to them by the instructors. Exercise protocol was three 10-minute cycle exercises at 50%, 60% and 70% of VO2 peak. The exercise was performed on a cycle ergometer. The total exercise duration was 30 minutes. Meal protocol consisted of 12 oz. of whole milk and a scoop of protein powder along with two toaster strudels. The total kcals for the meal was 721 kcal. The meal was to be consumed under a 10-minute time frame.

The results from this test showed heart rate to be higher the third trial of combining the TEF and TEE, then when exercise was performed alone with no meal. This study supports that there is a symbiotic relationship between the TEF and TEE and also provided numerous other references that supported this concept as well. Along with the evidence of a symbiotic relationship the increase in heart rate with the coupled effects of TEF and TEE support hypotheses 4 and 5. Since this study showed evidence of a meal increasing heart rate and the previous study showed the larger meal having greater effects, it is assumed that hypothesis 6 will be accepted. This study also provided information that the peak time was 45 minutes after consuming a meal.

3) Goben, Kent W., Gary A. Sforzo, and Patricia A. Frye. "Exercise Intensity and the Thermic Effect of Food." International Journal of Sport Nutrition 2.1 (1992): 87- 95. Web. 24 Oct. 2016

- Supports the symbiotic relationship between TEF and TEE
- Provides information on exercise intensity

The purpose of this study was to "investigate the effect of varying exercise intensity on the thermic effect of food (TEF)". The study included 16 lean male subjects between the age of 19-30, who performed either low or high intensity exercise. The physical status of the subject varied, but each were matched to a VO2 max group. Energy expenditure was recorded using indirect calorimetry. The meal for this study was in the form of a blend and totaled 750 kcals.

There were a total of three trials; meal only, meal and high intensity exercise and meal and low intensity exercise. Trials were performed at random to reduced ordered effects. Exercise protocol consisted of 30 minutes on a treadmill at the assigned intensity.

The results showed that coupling the two processes of TEF and TEE produced additive effects. There results also showed that there was a difference in effects for the two exercise intensities. The researcher used this information and added multiple intensities (light and moderate) into the exercise protocol.

4) Bradfield, Robert B., and Jourdan, Martin H. "Relative Importance of Specific Dynamic Action in Weight-Reduction Diets" *The Lancet*, vol. 302, no.7830, 1973, pp. 640-643., doi:10.1016/s0140-6736(73)92479-3

- Refutes hypothesis 3
  It was hypothesized that during exercise…
  - 3. The large meal will increase metabolic rate more than the small meal

The purpose of this study was to examine the "effect of varying the protein and calorie content of weight –reducing diets upon specific dynamic action". This included 6 obese women, who consumed a liquid diet for 10 days. 2 out of the 6 women did not complete the full duration of the experiment, therefore the results refer to the 4 women who completed the test. Oxygen consumption was measured under basal conditions for a 5-hour test period after the meal. The results from this study concluded that there was no significance difference in oxygen consumption when altering protein or calorie consumption.

Summary:

Research findings have aided in providing information that supports a symbiotic relationship, while other refute this. There is also controversy on the concept of altering meal size prior to exercise and the effects it has on the symbiotic relationship. Article 1 provides information that is supportive of meal size having a significant effect on the symbiotic relationship. While article 4 provides information that meal size does not have any significance on the symbiotic relationship. Both articles 1 and 4 were able to provide other important and useable information needed for the study. Articles 1 and 4 differed in the protocol and procedures, which allowed a range of ideas to come from looking at both studies. All hypotheses were able to be supported by research while some studies refuted the hypotheses. Overall there is still controversy on the idea of a symbiotic relationship between the TEF and TEE and the purpose of this study is investigate this concept more.

Chapter Three

Methodology

Protocol:

Participants for this study included two active females between the age of 19-21. The duration of the study included a total of four trials. The first trial was an orientation trial that aided in familiarizing the subject to the equipment and procedures for the experiment. The orientation trial was also a time for height, weight and steady state heart rate measures to be recorded. The second trial consisted of the subject being fasted (4-hour minimum) and performing exercise on the treadmill, while being hooked up to the Parvo Medics cart. The last two trials were performed at random and both consisted of consuming a meal prior to exercise. The meals differed in the amount of calories; a small and large meal. The small meal was a total of 496 calories and the large meal consisted of 822 calories.

The exercise for the three trials were all the same intensity. The two intensities performed for the experiment were light and moderate. The workload was based off of absolute heart rate for the individual, which was found in the orientation trial. The absolute heart rate for the light intensity was 120-125bpm and 130-145bpm for moderate intensity. The speed and grade were found in the orientation trial and served as a reference point for the rest of the experiment.

The large meal was composed of the following ingredients:

- 2 scoops of protein powder
- 1 cup of skim milk
- 1 cup of banana
- 1 container of yogurt
- 1 cup of egg whites
- ½ tbsp. of peanut butter powder
- Ice cubes
- ½ cup of water
- Total kcal: 822
- Volume: 24 oz.

The small meal was composed of the following ingredients:

- 1 scoop of protein powder
- 1 cup of skim milk
- ½ cup of banana
- 1 container of yogurt
- ¾ cup of egg whites
- ½ tbsp. of peanut butter powder
- Ice cubes
- 1 ½ cup of water
- Total kcal: 496

- Volume: 24 oz.

For both meals the ingredients were mixed together in a blender until the consistency was smooth and well mixed. The time limit for consumption was not to be over 45 minutes and not be under 30 minutes. The 30-45-minute time range was to allow the TEF to peak before adding in exercise.

Pretest protocol:

Measures taken to provide consistency for the subject were to avoid caffeine on the day of testing, as this would alter heart rate readings. Also it was urged that the subject be well rested on the day of testing. The subject was asked to come in at a minimal of 4 hours fasted so that the TEF from the prior meal wouldn't affect the testing. Lastly subjects were asked not to exercise prior to testing. Another pre-test protocol was to have the testing on the same days at the same time for each of the trials.

Equipment:

- Parvo medics cart
  - Nose plug
- Treadmill
- Thermometer
- Polar Heart Rate Monitor
  - Strap
  - Watch
- Weight scale

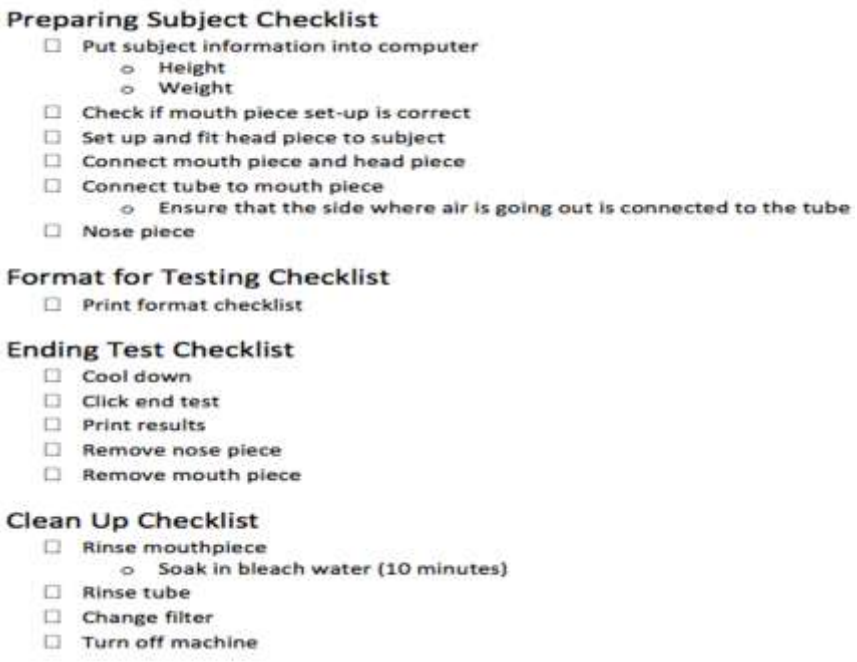
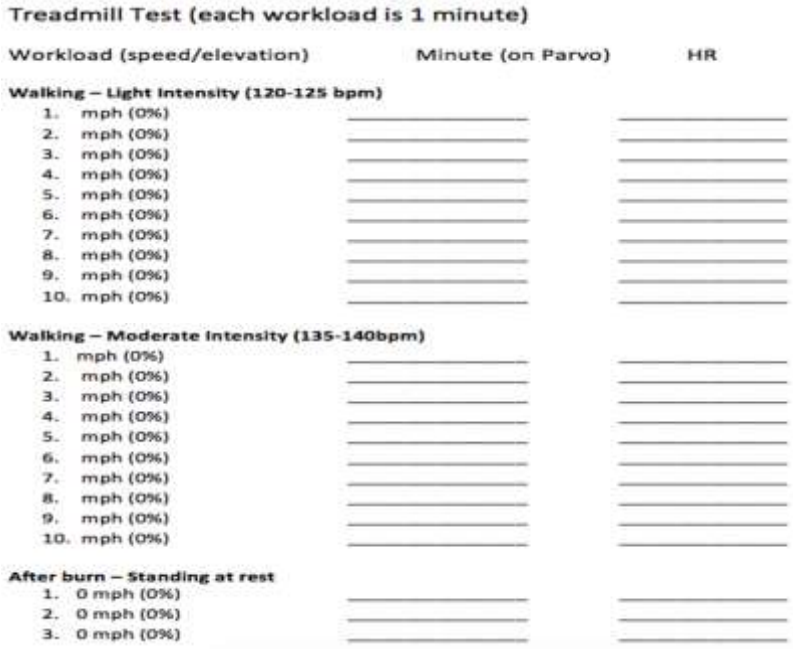


Figure 1. Shows all of the check lists needed for testing.

This sheet is useful to have before, during and after testing to ensure that all steps are taken.



Treadmill Test (each workload is 1 minute)

Workload (speed/elevation)	Minute (on Parvo)	HR
Walking – Light Intensity (120-125 bpm)		
1. mph (0%)	_____	_____
2. mph (0%)	_____	_____
3. mph (0%)	_____	_____
4. mph (0%)	_____	_____
5. mph (0%)	_____	_____
6. mph (0%)	_____	_____
7. mph (0%)	_____	_____
8. mph (0%)	_____	_____
9. mph (0%)	_____	_____
10. mph (0%)	_____	_____
Walking – Moderate Intensity (135-140bpm)		
1. mph (0%)	_____	_____
2. mph (0%)	_____	_____
3. mph (0%)	_____	_____
4. mph (0%)	_____	_____
5. mph (0%)	_____	_____
6. mph (0%)	_____	_____
7. mph (0%)	_____	_____
8. mph (0%)	_____	_____
9. mph (0%)	_____	_____
10. mph (0%)	_____	_____
After burn – Standing at rest		
1. 0 mph (0%)	_____	_____
2. 0 mph (0%)	_____	_____
3. 0 mph (0%)	_____	_____

Figure 2. Provides a representation of the outline used for recording measurements during testing.

This outline provides the researcher with step by step guidance in recording measurements. This sheet helps to minimize error that could occur during testing, which could alter the accuracy of results. After burn will continue for 10 minutes, although only 3 minutes is shown in the figure.

Procedures:

Parvo medics cart calibration:

Usage of the parvo medics cart requires two different calibration processes. First, before any calibration processes are started the machine must be turned on 30 minutes prior. Once warmed up the gas calibration process can begin. Steps in accurately doing this require the environmental conditions to be entered into the system. The readings for this include; temperature (°C), humidity (%) and barometric pressure (mmHg). The screen will then instruct you to turn on the calibration gas by turning the handle 90° counterclockwise. The gas in the calibration tank is composed of the following, 16.01% oxygen, 4.03% carbon dioxide. After the calibration gas entered and filled the chamber a reading was taken, which was used as a first reference point. The second reference point was taken when the room air entered and filled the chamber then that mixture was measured. The two different reference points were compared and either accepted or rejected. If accepted these values were used as reference points for a comparison of the gas exhaled from the subject, to then get the percentages of their air.

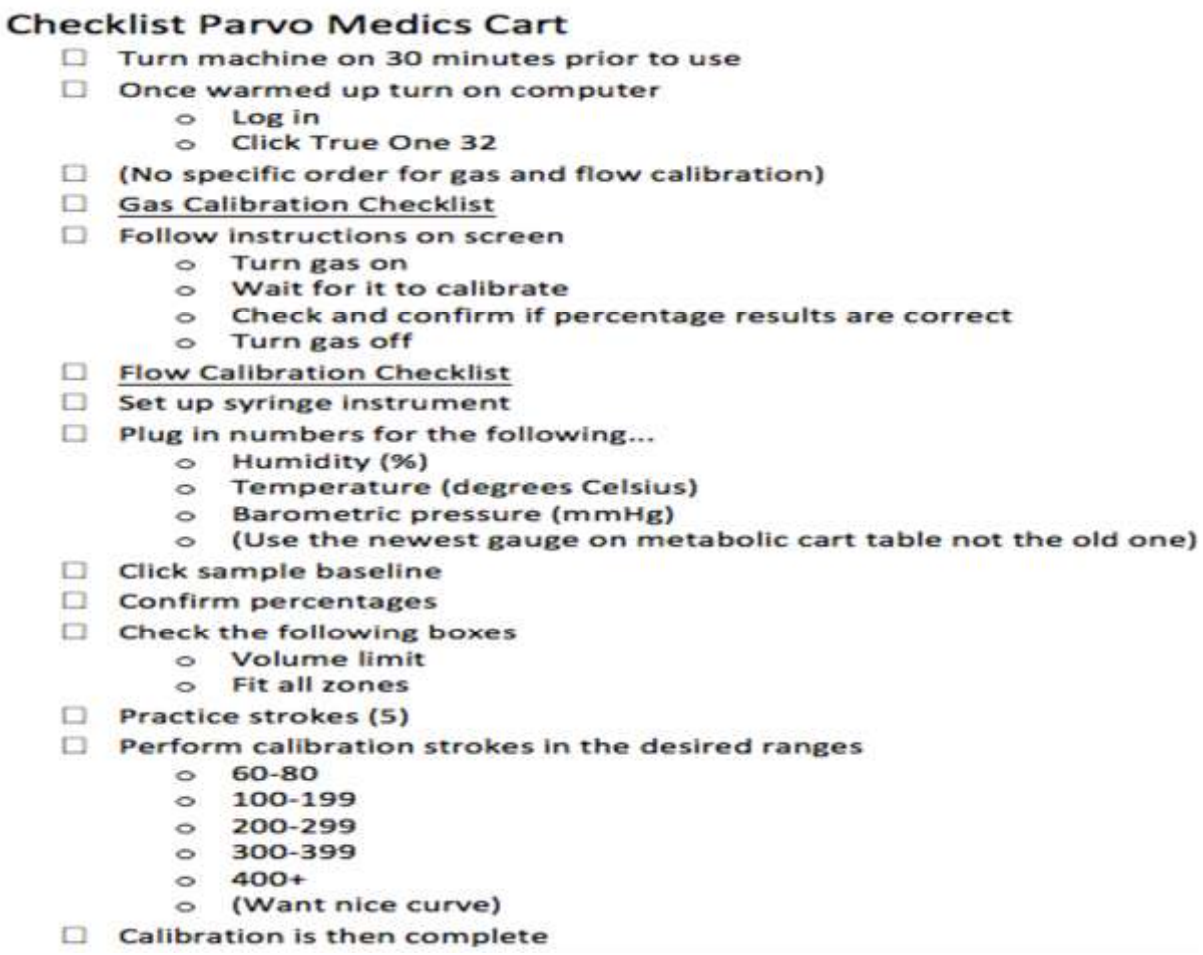
Once the gas calibration was complete the next step was to complete the flowmeter calibration. Note that the order of the two calibration processes is not important, the

significance is to ensure that both are completed. Steps for the flowmeter calibration include setting up the apparatus and completing the desired strokes. The apparatus included the pneumotach, which recorded the flow of air pressure. Another component was the water trap, which was critical in eliminating chance of liquids traveling into the chamber that would mess up readings. A plastic hose was then hooked onto the water trap, which connects to the two-way valve. The two-way valve was then connected to the 3-liter syringe, which completed the flow meter apparatus set up. The calibration process started when the first flush was completed. All flushes needed to be complete, meaning that the beginning and ending noise of each flush was heard. The first four flushes were practice strokes and were not taken for actual readings. Since they were practice strokes there were no speed requirements. But once the four practice strokes were completed the next five strokes needed to be in the correct ranges.

The stroke number and desired range is as follows below...

- Stroke 1: 60-80 L/min
- Stroke 2: 100-199 L/min
- Stroke 3: 200-299 L/min
- Stroke 4: 300-399 L/min
- Stroke 5: 400 L/min and up

The five strokes needed to be within that desired range or they would not be accepted. If they were in the desired range the end product should be a nice curve graph, if not the calibration strokes should be performed again.



Checklist Parvo Medics Cart

- ☐ Turn machine on 30 minutes prior to use
- ☐ Once warmed up turn on computer
  - Log in
  - Click True One 32
- ☐ (No specific order for gas and flow calibration)
- ☐ Gas Calibration Checklist
- ☐ Follow instructions on screen
  - Turn gas on
  - Wait for it to calibrate
  - Check and confirm if percentage results are correct
  - Turn gas off
- ☐ Flow Calibration Checklist
- ☐ Set up syringe instrument
- ☐ Plug in numbers for the following...
  - Humidity (%)
  - Temperature (degrees Celsius)
  - Barometric pressure (mmHg)
  - (Use the newest gauge on metabolic cart table not the old one)
- ☐ Click sample baseline
- ☐ Confirm percentages
- ☐ Check the following boxes
  - Volume limit
  - Fit all zones
- ☐ Practice strokes (5)
- ☐ Perform calibration strokes in the desired ranges
  - 60-80
  - 100-199
  - 200-299
  - 300-399
  - 400+
  - (Want nice curve)
- ☐ Calibration is then complete

Figure 3. Demonstrates the step by step checklist for the calibration processes needed to calibrate the parvo medics cart.

This checklist serves to ensure that all step by step instructions are taken so that the parvo medics cart can be calibrated properly. If steps are missed or not completed properly this increases the chance for error in the end results.

Orientation trial:

- Height and weight were recorded
- Polar monitor was placed on subject under bra line
- Polar watch was placed on parvo medics cart table
- Assembly of mouth piece
- Connected mouth piece to head gear
- Entered subject information into parvo medics cart
- Place head piece and mouth piece on subject
- Placed nose piece on subject
- Started testing on parvo medics cart
- Subject stood at rest on treadmill while hooked up to the cart
- Allowed 6 minutes to pass

- Subject began walking at a light pace
- Heart rate measurements were taken at the end of each minute
- Speed and grade were altered until the researcher determined a steady state heart rate for light intensity
    - 120-125 bpm
- Researcher paused testing
- Removed mouth and head piece
- Cleaned spit trap
- Placed mouth and head piece on subject
- Began testing again
- Increased pace to moderate
- Heart rate measurements were taken at the end of each minute
- Speed and grade were altered until the researcher determined a steady state heart rate for moderate intensity
    - 135-140 bpm
- The subject was unhooked
- Posttest protocol measures were taken (shown in figure 1)

Fasted trial:

- Weight was recorded
- Researcher calibrated parvo medics cart (shown in figure 3)
- Assembled mouth piece
- Connected mouth piece to head piece
- Entered in subject information into parvo medics cart
- Placed head piece and mouth piece on subject
- Placed nose piece on subject
- Started testing on parvo medics cart
- Subject stood at rest on treadmill while hooked up to the cart
- Allowed 6 minutes to pass
- Heart rate measurements were taken at the end of each minute
- Subject began walking at the speed and grade found in the orientation trial for light intensity exercise
- This intensity lasted for 10 minutes
- Researcher paused testing
- Removed mouth and head piece
- Cleaned spit trap
- Placed mouth and head piece on subject
- Began testing again
- Set speed and grade for moderate intensity, which was found in the orientation trial
- 10 minutes was allotted for this intensity
- Heart rate was taken after each minute
- Once 10 minutes was completed the researcher stopped the treadmill

- Subject was instructed to stand at rest on the treadmill while still being hooked up to the cart
- The after burn period lasted for 15 minutes
- Heart rate measurements were taken at the end of every minute
- Once 15 minutes passed the test was ended
- The subject was unhooked
- Posttest protocol measures were taken (shown in figure 1)

Small meal trial:

- Weight was recorded
- Researcher calibrated parvo medics cart (shown in figure 3)
- Assembled mouth piece
- Connected mouth piece to head piece
- Entered in subject information into parvo medics cart
- Placed head piece and mouth piece on subject
- Placed nose piece on subject
- Started testing on parvo medics cart
- Subject stood at rest on treadmill while hooked up to the cart
- Allowed 6 minutes to pass
- Heart rate measurements were taken at the end of each minute
- Subject began walking at the speed and grade found in the orientation trial for light intensity exercise
- This intensity lasted for 10 minutes
- Researcher paused testing
- Removed mouth and head piece
- Cleaned spit trap
- Placed mouth and head piece on subject
- Began testing again
- Set speed and grade for moderate intensity, which was found in the orientation trial
- 10 minutes was allotted for this intensity
- Heart rate was taken after each minute
- Once 10 minutes was completed the researcher stopped the treadmill
- Subject was instructed to stand at rest on the treadmill while still being hooked up to the cart
- The after burn period lasted for 15 minutes
- Heart rate measurements were taken at the end of every minute
- Once 15 minutes passed the test was ended
- The subject was unhooked
- Posttest protocol measures were taken (shown in figure 1)

Large meal trial:

- Weight was recorded

- Researcher calibrated parvo medics cart (shown in figure 3)
- Assembled mouth piece
- Connected mouth piece to head piece
- Entered in subject information into parvo medics cart
- Place head piece and mouth piece on subject
- Placed nose piece on subject
- Started testing on parvo medics cart
- Subject stood at rest on treadmill while hooked up to the cart
- Allowed 6 minutes to pass
- Heart rate measurements were taken at the end of each minute
- Subject began walking at the speed and grade found in the orientation trial for light intensity exercise
- This intensity lasted for 10 minutes
- Researcher paused testing
- Removed mouth and head piece
- Cleaned spit trap
- Placed mouth and head piece on subject
- Began testing again
- Set speed and grade for moderate intensity, which was found in the orientation trial
- 10 minutes was allotted for this intensity
- Heart rate was taken after each minute
- Once 10 minutes was completed the researcher stopped the treadmill
- Subject was instructed to stand at rest on the treadmill while still being hooked up to the cart
- The after burn period lasted for 15 minutes
- Heart rate measurements were taken at the end of every minute
- Once 15 minutes passed the test was ended
- The subject was unhooked
- Posttest protocol measures were taken (shown in figure 1)

Pilot Data:

Pilot data collected consisted of the first blended meal being a large meal trial of a 1,000 calorie shake. The consistency of this blend was extremely thick, foamy and unappealing for the subject. The subject reported that it was very heavy and uncomfortable to perform exercise after consumption of the meal. Another error with this trial was that the steady state heart rates were not found. Therefore, the workload during the trial was not consistent and the results were not accurate.

Changes from the previous trial include the researcher lessening the number of calories for the large meal down to 800 calories. Another reason for decreasing the amount of calories is to represent a daily meal that an individual would consume. For the next blend the researcher used a more caloric dense protein powder along with adding additional ingredients. The two changes to the blend made the volume of the blend decrease, which was more appealing to the subject. Another change was making sure to have an orientation trial in which

ensured that the steady state heart rates were found. Also creating the necessary checklists so that error could be minimized for future tests.

The next area of pilot data consisted of getting a crash course on the parvo medics cart that the researcher would be using. The crash course was taught by two professors at the college. The crash course consisted of going through step by step walk through of calibration and testing procedures. On another day we used a student from class who served as a subject for a crash trial course. The subject performed on a cycle ergometer for a short duration of time. The printed results from this study served as a template for what we could expect with each trial. The results were then discussed in a way that pertained to each individual study.

The researcher then gained more experience with working with the parvo medics cart through assisting with another study for a peer. Experience was gained by working independently through the calibration and testing protocol. Although this was a VO2 max the set up for testing and parvo medic calibration was still the same, which helped the researcher gain more experience.

The next and largest part of the pilot data comes from performing the procedures for this study with a friend of the researcher. The researcher along with the professor performed an orientation trial with subject 1. This trial followed all orientation protocol steps. This served as a reference point for finding the wait time of 6 minutes to begin testing. For this subject the speed for light intensity was 2.9 mph and the grade was 0%. The speed for moderate intensity was 3.4 mph and the grade was 0%.

The fasted trial was the next performed for subject 1. All steps listed for the fasted trial were taken and no problems were incurred. The next trial was the large meal. All steps listed for the large meal trial were taken and no problems were incurred. Lastly the small meal trial was performed. All steps were taken for the small meal protocol. Small problems were incurred during this trial that included the consistency of the blend and consumption time. For the small meal blend the consistency was foamier than the large meal and made it harder to consume for the subject. The difference in consistency lead to a difference in consumption time. The large meal consumption time was 35 minutes while the small meal consumption time was 55 minutes.

An important point that arose when working with the blend was the volume of the two blends. The professor suggested that to ensure the outcomes were solely dependent upon the difference in calories, it would be important to keep volume for the two blends the same. This was taken into consideration for the pilot data trial.

While reviewing the results from the pilot data trials there was error in the data from subject 1. The VO2 values and METS were extremely low. The researcher then tested herself during light and moderate exercise to see if there was error with the machine. The values from this test were more accurate than subject 1. This led the researcher to believing that the error was with the subject rather than the machine.

After the collection of pilot data there were control measures that the researcher wanted to add to the study. Additional control measures include only performing testing on the same days at the same time for each test. Also being stricter on consumption time of the shake. The following control measures will help to decrease the chance of error and variation in the results.

Pilot Data Results:

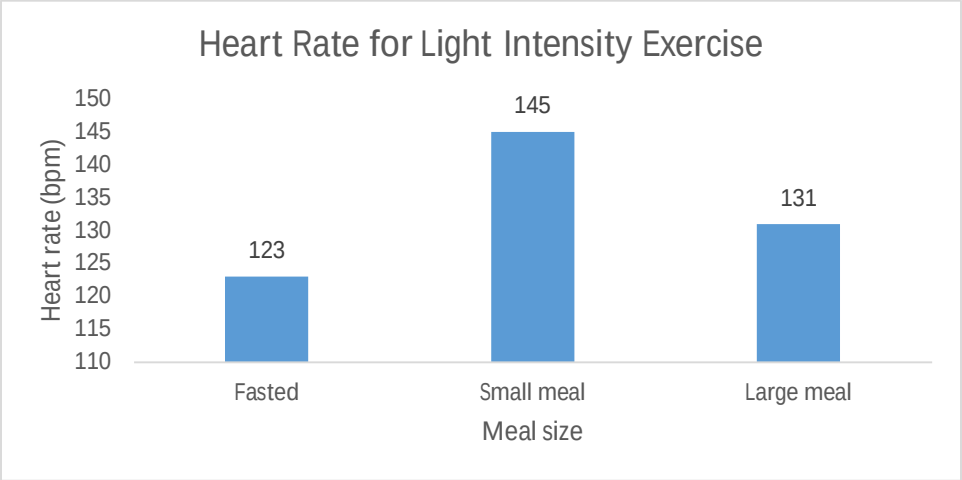


Figure 4. Displays the heart rate (bpm) for the three trials during 10 minutes of light intensity exercise.

The figure shows there was a 17% increase from the fasted to small meal trial. There was a 7% increase from the fasted to large meal. But there was a 9% decrease from the small meal to large meal.

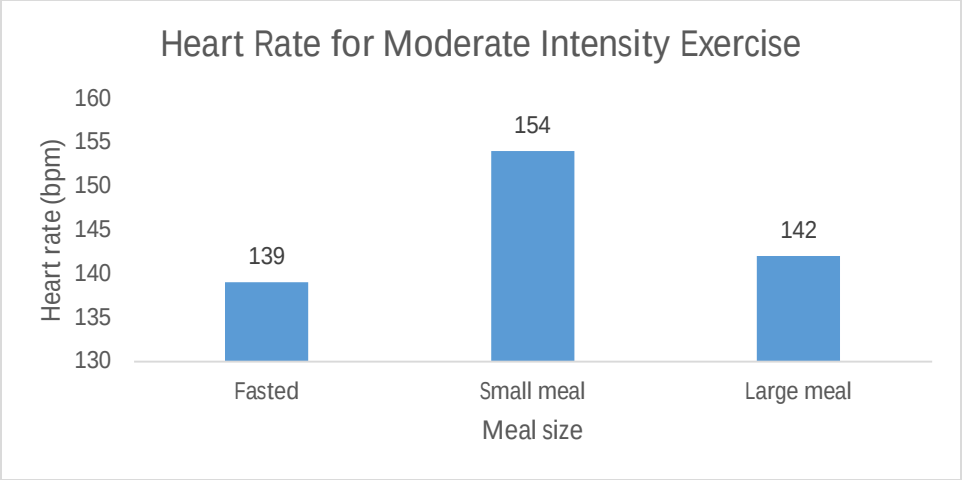


Figure 5. Shows the heart rate (bpm) for the three trials during 10 minutes of moderate intensity exercise.

The figure shows a 11% increase from the fasted to small meal trial. A 2% increase from the fasted to large meal trial. Then there was an 8% decrease from the small meal to large meal.

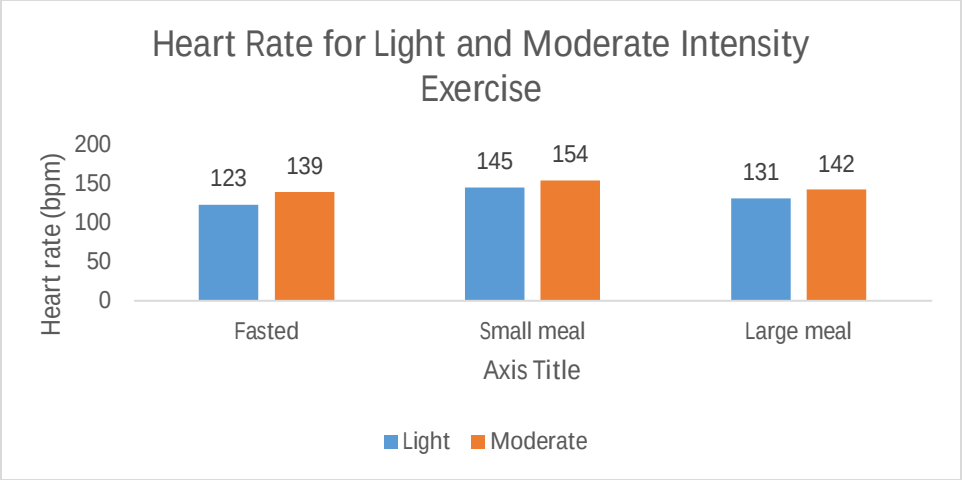


Figure 6. Demonstrates the heart rate (bpm) for the three trials during light and moderate intensity exercise.

This gives a visual representation of the different meal trials and intensities compared side by side.

It was hypothesized that during exercise...

4. The small meal will increase heart rate - ACCEPTED
5. The large meal will increase heart rate - ACCEPTED
6. The large meal will increase heart rate more than the small meal - REJECTED

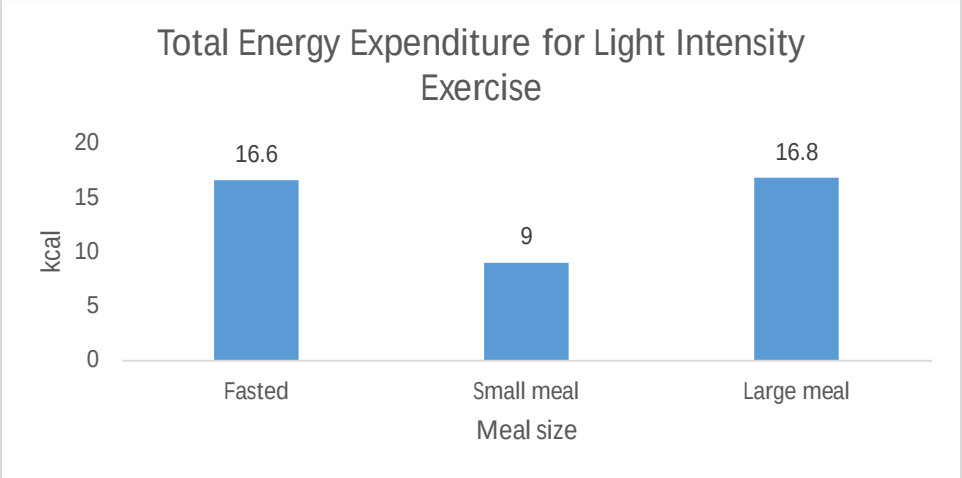


Figure 7. Displays the total energy expenditure (kcals) for the three trials for 10 minutes of light intensity exercise.

The figure shows a 45% decrease from the fasted to small meal trial. A 1.2% increase from the fasted to large meal trial. Then there was an 46% increase from the small meal to large meal.

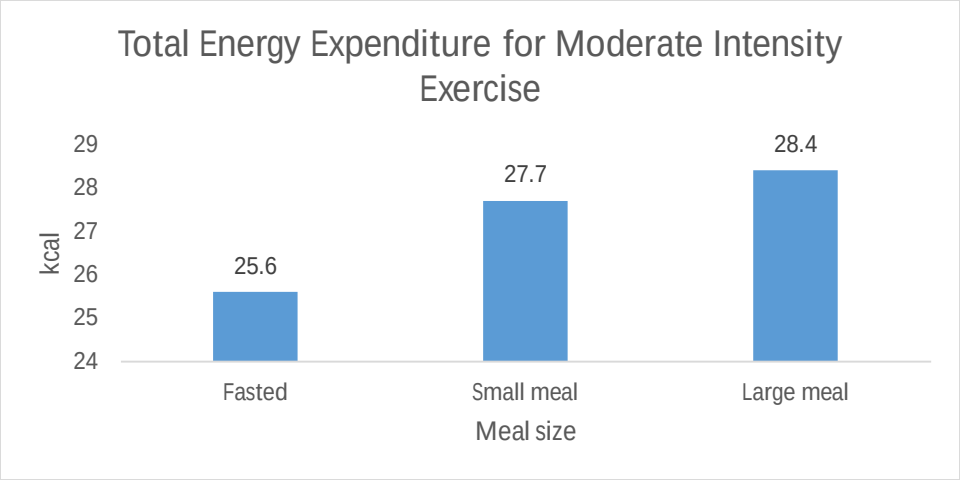


Figure 8. Displays the total energy expenditure (kcals) for the three trials for 10 minutes of moderate intensity exercise.

The figure shows an 8% increase from the fasted to small meal trial. A 11% increase from the fasted to large meal trial. Then there was an 2% increase from the small meal to large meal.

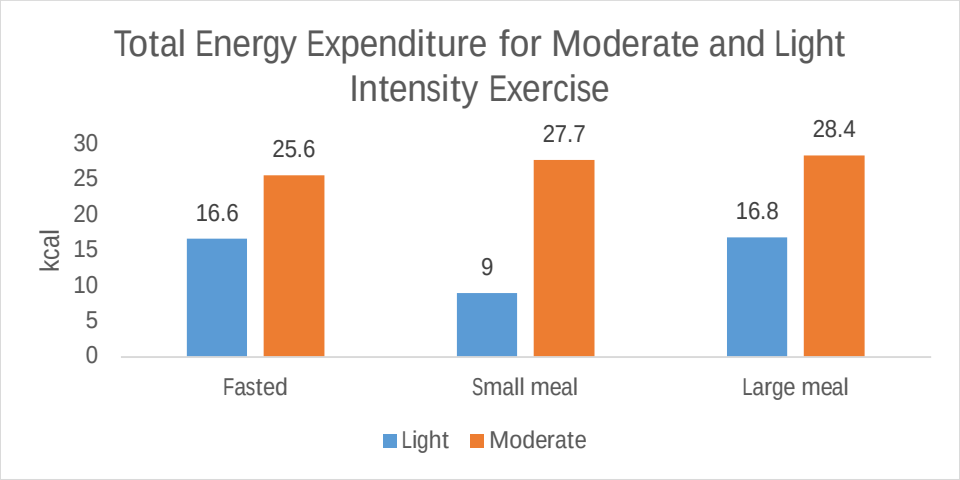


Figure 9. Demonstrates the total energy expenditure (kcals) for the three trials for light versus moderate intensity exercise.

This gives a visual representation of the different meal trials and intensities compared side by side.

It was hypothesized that during exercise...

1. The small meal will increase metabolic rate - ACCEPTED
2. The large meal will increase metabolic rate - ACCEPTED
3. The large meal will increase metabolic rate more than the small meal - ACCEPTED

Pilot Data Discussion:

Evidence for a symbiotic relationship for the TEF and TEE was shown from the results of the pilot data. The meal trials had a greater impact on heart rate when compared to the trial with no meal consumption prior to exercise. Also the meal trials had a greater outcome on metabolic rate when compared to the no meal trial. The greater outcomes on metabolic rate and heart rate when combining a meal and exercise supports hypotheses and agree with research.

Looking further into the symbiotic relationship between the TEF and TEE it is important to see the outcome of exercise intensity and meal size. For exercise intensity figures 9 and 6 show that the higher intensity exercise had a higher outcome on both heart rate and metabolic rate. Then looking at the meal size comparison between the small and large meal shows a slight difference than what was hypothesized. The small meal generated a higher heart rate when compared to the larger meal for both light and moderate intensity exercise. This did not support hypothesis 6.

Looking specifically at figure 7 it is clear that there was error in this area. From the fasted to small meal it shows that there is a 45% decrease in energy expenditure. This large of a decrease is not accurate. It was hypothesized that it could be due to error with the machine, so the researcher investigated that problem more. The self-test that the researcher performed on herself provided accurate results, which indicated that error might be with subject 1 rather than error with the machine.

Future changes from the pilot data include performing testing on the same days at the same time, so that error can be minimized. Also perfecting the blend so that the small meal consistency is not foamy. Lastly the stricter regulation on meal consumption time will be monitored to provide accuracy between the two meals.

Summary:

Some important pilot data work was made when experimenting with the blend consistency and ingredients. The final two blends were similar in that their volume was the same. Making sure the small and large meal have the same volume aids in knowing that the only reason for increase in outcomes is from the difference in the number of calories. The results from the pilot data prove that a symbiotic relationship exists between the TEF and TEE. Meal size did show significance for moderate intensity exercise, while there was error causing the results for the light intensity exercise to be inaccurate. The results do not agree with all hypotheses, due to the fact that the small meal generated larger outcomes when compared to the large meal during light exercise.

Summary of Hypotheses:

It was hypothesized that during exercise…

1. The small meal will increase metabolic rate - SUPPORTED
2. The large meal will increase metabolic rate - SUPPORTED
3. The large meal will increase metabolic rate more than the small meal - SUPPORTED

4. The small meal will increase heart rate - SUPPORTED
5. The large meal will increase heart rate - SUPPORTED
6. The large meal will increase heart rate more than the small meal - REFUTED

Chapter Four

Results

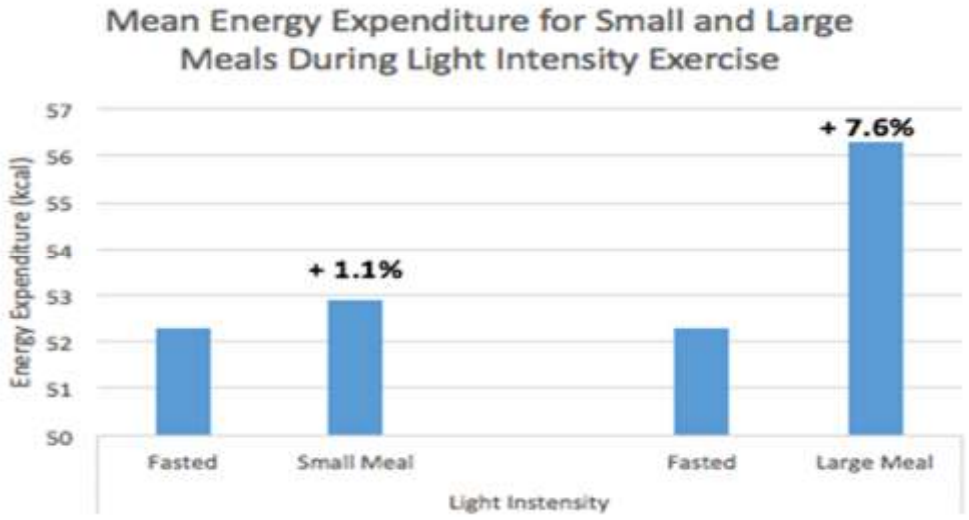


Figure 1. Displays the mean energy expenditure (kcal) for the small and large meal trials compared to the fasted trial during light intensity exercise.

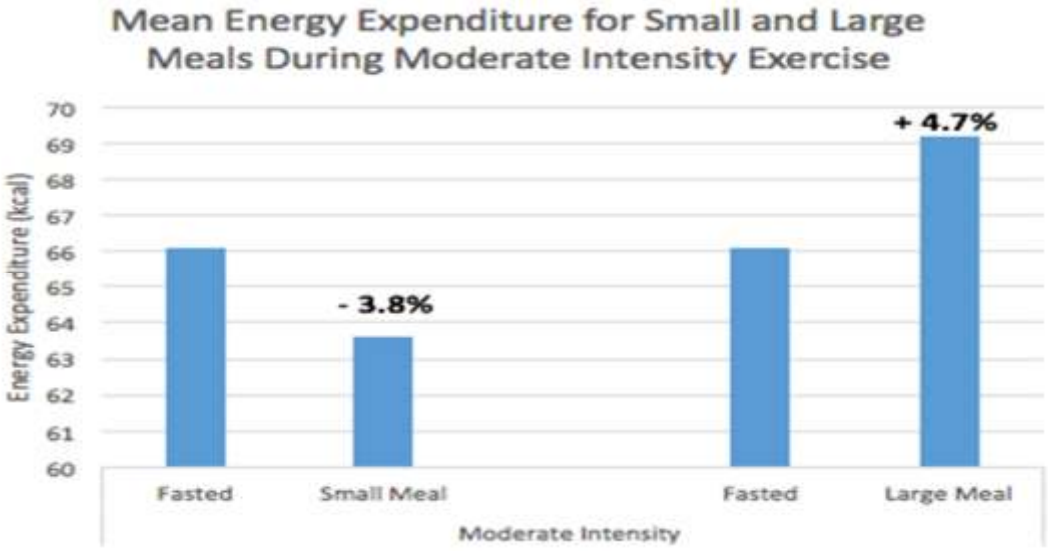


Figure 2. Displays the mean energy expenditure (kcal) for the small and large meal trials compared to the fasted trial during moderate intensity exercise.

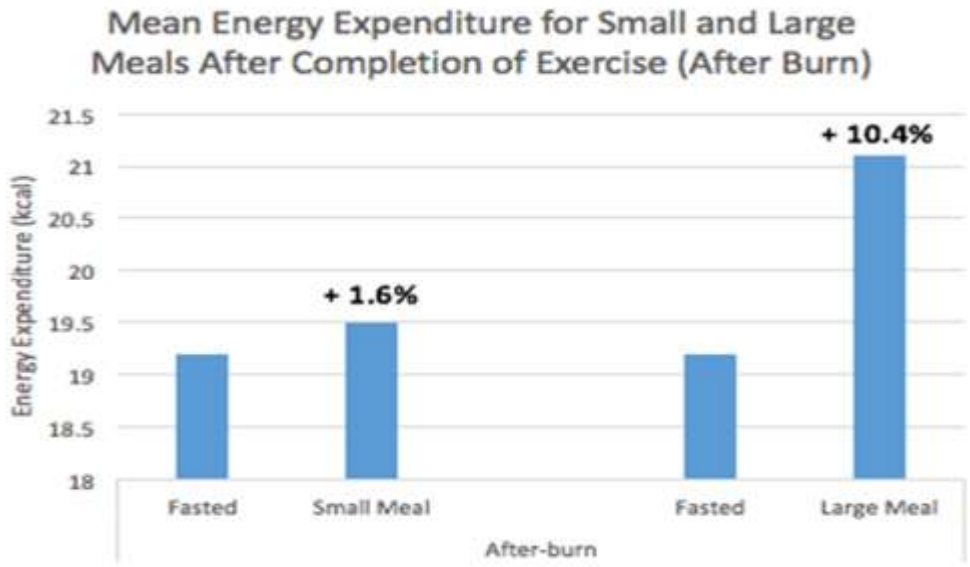


Figure 3. Displays the mean energy expenditure (kcal) for the small and large meal trials compared to the fasted trial during the after burn period.

The light intensity trial for a small meal showed a 1.1% increase when compared to the light intensity fasted trial. Then looking at the large meal for light intensity it had a 7.6% increase when compared to the fasted trial. This resulted in the larger meal having a more significant effect on energy expenditure during light intensity exercise.

The moderate intensity exercise for a small meal showed a 3.8% decrease in energy expenditure when compared to the fasted trial. Then looking at the large meal for moderate intensity there was a 4.7% increase when compared to the fasted trial. This concluded that the larger meal had a more significant effect on energy expenditure during moderate intensity exercise. For example, if someone were to burn 120 kcal by walking at this pace for 30 minutes and then were to change the time of the meal and walk then a total of 125.6 kcal would be expended.

Both intensities showed an increase in energy expenditure, besides the small meal and moderate intensity trial which showed a decrease. The increase in energy expenditure from the no meal and meal trials suggests that there is a symbiotic relationship between the TEF and TEE.

The after burn period consisted of standing at rest for 10 minutes on the treadmill while being hooked up to the parvo medics cart. For the small meal there was a 1.6% increase in energy expenditure when compared to the fasted trial. Then for the large meal there was a 10.4% increase in energy expenditure when compared to the fasted trial. This showed that there was a more significant effect on energy expenditure for the large meal during the after burn period than there was for the small meal.

The increase in energy expenditure after exercise has stopped for both the small and large meal shows that the symbiotic relationship is still present even after exercise. It also resulted in the large meal having a greater energy expenditure when compared to the fasted and small meal trials.

Summary

It was hypothesized that during exercise…

1. The small meal will increase metabolic rate: ACCEPTED
2. The large meal will increase metabolic rate: ACCEPTED
3. The large meal will increase metabolic rate more than the small meal: ACCEPTED
4. The impact of a meal combined with moderate intensity exercise will be greater than the impact of a meal combined with light intensity exercise: ACCEPTED

Chapter Five

Discussion

The purpose of this study was examining whether or not a symbiotic relationship exists between the thermic effect of food (TEF) and thermic effect of exercise (TEE). This study also looked at altering components of TEF and TEE. Altering meal size for TEF was including a small and large meal in different trials. Altering the exercise was different exercise intensities for each trial.

The question that was researched during this study was that if there was a symbiotic relationship between the TEF and TEE? Other questions then followed this question; such as does meal size have an effect on this relationship? and does exercise intensity have an effect on the relationship? All while looking at the "bonus burn" of calories that is expended from the symbiotic relationship.

Results Analysis

Looking at the three main questions…

1. Is there a symbiotic relationship?
2. Does exercise intensity affect the relationship?
3. Does meal size influence the relationship?

and pairing those with the four hypotheses is what will be analyzed in this section.

The first two hypotheses look solely at the idea of energy expenditure increasing with the addition of a meal before performing exercise. Both hypotheses were accepted after analyzing the results. This in turn supports the first question of there being a symbiotic relationship between the TEF and TEE.

- *Hypothesis 1*: The small meal will increase metabolic rate: ACCEPTED
- *Hypothesis 2*: The large meal will increase metabolic rate: ACCEPTED

Looking at both hypothesis 1 and 2 and seeing how they are both accepted lead to the idea of SNS stimulation. The sympathetic nervous system (SNS) is turned on during both exercise and during digestion, but what happens when these two processes of the TEF and TEE are occurring together rather than separately? This can be the answer as to why there is a bonus burn of calories, which is due to the over stimulation of the SNS since both processes TEF and TEE are turning it on.

The third hypothesis was also accepted, which is taking question number 3 into consideration. This hypothesis accepts the idea of a symbiotic relationship between the TEF and TEE and supports that meal size will have an effect on this relationship. The hypothesis was accepted which supports that a larger meal had a greater effect on metabolic rate than when compared to the small meal.

- *Hypothesis 3*: The large meal will increase metabolic rate more than the small meal: ACCEPTED

The reasoning of why the larger meal would have a greater effect on metabolic rate could also be explained through the SNS. Since a larger meal is entering the body the SNS could potentially be turned on more and for longer than it would with a small meal. Therefor the large meal is going to challenge the SNS more than what a small meal would and cause the metabolic rate to increase more.

Lastly, the fourth hypothesis was also accepted, which was examining the effects of the two exercise intensities when combined with a meal. This hypothesis can help to answer question number 3, which is looking at if exercise intensity has an effect on the symbiotic relationship.

- *Hypothesis 4*: The impact of a meal combined with moderate intensity exercise will be greater than the impact of a meal combined with light intensity exercise: ACCEPTED

This hypothesis was generated due to the idea of a greater exercise intensity leading to a larger energy expenditure when compared to a lighter intensity exercise. This is true because during exercise the working muscles require blood and nutrient supply to that area. Increasing the exercise intensity, then increases the need for supply; therefor the body has to work harder to get it done, which requires more energy.

Additional Research

Multiple studies have been conducted on this topic, which have both rejected and accepted the idea of a symbiotic relationship of the TEF and TEE. Numerous studies have also looked at different factors and how altering those can affect the symbiotic relationship. This study accepted that there is a symbiotic relationship present between the TEF and TEE.

Continued research on this topic would be beneficial and potentially be very useful. Since this study only examined altering the meal size and exercise intensity it would interesting to examine other factors and the effects each has on the relationship. Factors such as is there a threshold for meal size on the symbiotic relationship? This study only examined two meals that were close to 500kcal and 1000kcal, could meals larger, smaller or between those kcal range give the same or different effects?

Examining different aspects of the symbiotic relationship would allow for greater knowledge on the relationship. Since the time for this study was limited it lead to a smaller number of subjects. A future study could be tested on a larger scale with more subjects. Also altering the factors of the subjects' such as age, gender, physical fitness, etc. would make for an interesting study.

Looking into the different studies and aspects that can be covered can be very beneficial for receiving information on this topic. The more data gathered can lead to more helpful information to find out what can be done to increase energy expenditure more significantly.

Conclusion

Overall this study was examining if a larger meal would produce a greater symbiotic effect, therefore leading to a greater energy expenditure. This study is universal in that most people perform physical activity such as walking and people consume food daily. The results of this study were intended to show what meal size and exercise intensity correlate to a larger energy expenditure.

Since people have a multitude of excuses for working out and not getting the adequate amount of physical activity this study was intended to help that. Vigorous exercise, weight lifting and other forms of exercise include the time it takes to prepare and clean up afterwards, along with the time being 30 minutes to an hour for the actual workout. These activities consume a lot of time, in which light to moderate walking does not. Walking can be done in any clothes, anywhere, anytime with no equipment or preparation needed.

In both exercise intensities there is an increase in energy expenditure and there was a greater increase when the TEF was paired with the TEE. This supports that eating a meal and then going for a walk afterwards is going to give individuals the "bonus burn" of calories. Although the percentages may look small, it can be helpful to look at it in a larger scale.

The American Heart Association (AHA) suggests 150 minutes of moderate exercise per week to improve cardiovascular health. This 150 minutes per week breaks down roughly into 22 minutes of moderate exercise per day. If subject 1 normally burns 124 kcal normally during light exercise and then switches the time of walk after consuming a large meal she would then expend 132 kcal. She would then be expending 10 more kcals per walk by not doing anything different, but changing the timing of her meal and walk. While 10 kcals might not seem like a big difference when looking at it in terms of one day. Looking at it in terms of one year can be very eye opening. 10 kcal/day for 365 days = 3,650kcal expended, which is more than 1lb of fat. 3,500 kcals are what makes up 1 pound of fat and this person can burn that just by switching the time of their meal and their walk.

The above example was for light intensity exercise and a large meal, now let's look at what happens when moderate intensity is paired with a large meal. If subject one normally expends 154kcal during a 22-minute walk and then would expend 162kcal if she consumed her large meal before exercise. That would be an 8 kcal difference, which is slightly lower than the light intensity exercise expenditure, but still significant. During a year period that would still add up to a "bonus burn" of 2,920 kcals.

The bonus burn of calories may seem small on a daily basis, but if continued over time it might serve as an important technique to combat obesity and help aid in weight loss. Also the person does not have to put in extra time, intensity, money, etc., all that is to be changed is the timing of the meal with the walk and you can achieve this bonus burn of caloric expenditure.

References

1. Belko, Amy Z., et al. “Effect of energy and protein intake and exercise intensity on the thermic effect of food.” *Nutrition Research*, pp. 863-869., doi:10.1016/s0271-5317(87)80013-1.
2. Bradfield, Robert B., and Jourdan, Martin H. “Relative Importance of Specific Dynamic Action in Weight-Reduction Diets” *The Lancet*, vol. 302, no.7830, 1973, pp. 640-643., doi:10.1016/s0140-6736(73)92479-3
3. Fox, Stuart Ira. Human physiology. McGraw-Hill, 2011.
4. Goben, Kent W., Gary A. Sforzo, and Patricia A. Frye. "Exercise Intensity and the Thermic Effect of Food." International Journal of Sport Nutrition 2.1 (1992): 87- 95. Web. 24 Oct. 2016
5. Haxhi, Jonida, et al. “Exercising for Metabolic Control: Is Timing Important.” *Annals of Nutrition and Metabolism*, vol. 62, no. 1, 2013, pp. 14-25., doi:10.1159/000343788.
6. Hill JO, et al. “Meal Size and Thermic Response to Food in Male Subjects as a Function of Maximum Aerobic Capacity.” Metabolism: Clinical and Experimental, vol. 33, no. 8, 1984, pp. 743–9.
7. Himms-Hagen, Jean. “Role of thermogenesis in the regulation of energy balance in relation to obesity.” *Canadian Journal of physiology and Pharmacology*, vol. 67, no. 4, 1989, pp. 394-401., doi:10.1139/y89-063.
8. Jonee, Lilian De, and George A. Bray. “The Thermic Effect of Food and Obesity: A Critical Review.” *Obesity Research*, vol. 5, no. 6, 1997, pp. 622-631., doi:10.1002/j.1550-8258.1997.tb00584.x.
9. Kang J, et al. “Metabolic Responses during Postprandial Exercise.” Research in Sports Medicine (Print), vol. 21, no. 3, 2013, pp. 240–52., doi:10.1080/15438627.2013.792088.
10. Kinabo, J. L., and J. V. G. A. Durnin. "Thermic Effect of Food in Man: Effect of Meal Composition, and Energy Content." British Journal of Nutrition 64.01 (1990): 37. Web.
11. “National Center for Health Statistics.” Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 3 May 2017, www.cdc.gov/nchs/fastats/obesity-overweight.htm.
12. Sobol, S. J., et al. “Thermic Effects of Food and Exercise in Trained and Sedentary Women.” Medicine & Science in Sports & Exercise, vol. 18, no. supplement, 19 Jan. 1987, doi:10.1249/00005768-198604001-00446.
13. Swindells, Yola E. “The Influence of Activity and Size of Meals on Caloric Response in Women.” *British Journal of Nutrition*, vol. 27, no. 01, 1972, p. 65., doi:10.1079/bjn19720070.
14. Zahorska-Markiewicz, B. “Thermic effect of food and exercise in obesity.” European Journal of Applied Physiology and Occupational Physiology, vol. 44, no. 3, 1980, pp. 231–235., doi:10.1007/bf00421622.

Appendix

Appendix I

Class: Kinesiology and Integrative Physiology Senior Thesis Study
Research Title: Thermic Effect of Food and Exercise; Are They Symbiotic?
Researcher: Courtney Buchanan

Informed Consent

This study is part of the Senior Thesis requirement for the Kinesiology and Integrative Physiology major at Hanover College. The following statement will provide the purpose and procedures for this study along with risks and precautions to guarantee safety. Personal responsibilities will also be listed to ensure that the participant knows what is expected.

The purpose of this study is to investigate the combined impact on the thermic effect of food (TEF) and the thermic effect of exercise (TEE) on metabolic response. The relationship between the Thermic Effect of Food and Exercise is what is going to be observed during this experiment. This is going to require use of the treadmill, heart rate monitor and parvo medics cart.

Your participation can be summarized as follows:

- Orientation trial: during this trial there will be initial measurements taken; height, weight, heart rate (during exercise and at rest). This will also be the time when you will be familiarized with the treadmill, heart rate monitor and parvo medics cart. You will then be hooked up to the parvo medics cart and asked to perform light (120-125 bpm) and moderate (135-140bpm) exercise on the treadmill. It is also asked that you be a minimum of 4 hours fasted at this time.
- Fasted trial: during this trial you will also be asked to be a minimum of 4 hours fasted and your weight will be recorded. You will be hooked up to the parvo medics cart and heart rate monitor, then perform light (120-125 bpm) intensity exercise for 10 minutes, rest and then perform moderate intensity (135-140bpm) exercise for 10 minutes. You will then stand at rest on the treadmill for 15 minutes, while still being hooked up to the equipment.
- Blend trial 1: during this trial you will also be asked to be a minimum of 4 hours fasted and your weight will be recorded. You will be asked to consume a protein shake blend made by the researcher. You will be hooked up to the parvo medics cart and heart rate monitor and perform light intensity (120-125 bpm) exercise for 10 minutes, rest and then perform moderate intensity (135-140bpm) exercise for 10 minutes. You will then stand at rest on the treadmill for 15 minutes while still being hooked up to the equipment.
- Blend trial 2: during this trial you will also be asked to be a minimum of 4 hours fasted and your weight will be recorded. You will be asked to consume a protein shake blend made by the researcher. You will be hooked up to the parvo medics cart and heart rate

monitor and perform light intensity (120-125 bpm) exercise for 10 minutes, rest and then perform moderate intensity (135-140bpm) exercise for 10 minutes. You will then stand at rest on the treadmill for 15 minutes while still being hooked up to the equipment.

Associated Risks

Please report any know food allergies in the section below, so that you can be excused from the study if that particular food is in the blend. Other risks include injury that could result from using a treadmill. If at any time you feel that you are at risk for injury, please let the researcher know. Steps will be taken to minimize this risk and the intensity is low enough that injury risk should be minimal. You will remain anonymous and all personal information will be kept confidential. Your participation in the study is completely voluntary, therefore, you can dismiss yourself from the study at any given time.

Since exercise is associated with this study it is asked that if you aware of any health problems that could cause risk to your well-being that you not continue with the study. These conditions and others are as follows:

- High blood pressure
- Known heart condition
- Diabetes
- Illness within the past week
- On current prescription medication
    - Altering heart rate

If there are any other conditions that are not listed, but concern you please feel free to ask the researcher.

List any food allergies in the space below:

Questions

If you have any questions, feel free to contact the researcher Courtney Buchanan at buchananc18@hanover.edu or Dr. Bryant Stamford at Stamford@hanover.edu.

Statement of Consent

I know what is expected as a participant in this study and have read all the above information. You acknowledge that you do not have any of the following risk factors for performing exercise. It has also clear that you are subject to discontinue your participation at any time without explanation or consequence. I consent to participate in this research study.

Printed Name of Participant: _____

_____ _____

Signature of Participant: Date

_____ _____

Signature of Researcher Date

Appendix II

IRB Approval

Study number 2017102, titled Thermic Effect of Food and Thermic Effect of Exercise; Are They Symbiotic? has been approved by the Hanover College Institutional Review Board. The study was classified as "Expedited."

Specifically, the IRB that the study qualified as Expedited4: "Category 4: Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.) Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amount s of energy into the subject or an invasion of the subject=s privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual." [reference].

This approval authorizes the authors of this application to begin data collection. This approval will expire on Nov 28, 2018.

Any changes to the procedure must be approved by the IRB approval to making those changes. Authors may request a modification to their procedure by logging in to irb.hanover.edu, navigating to the approved application, going to the Submit section, and clicking the *Request Modification* button. This will create a clone of the original application with a new study number, to which modifications can be made. If you have any questions, please contact either the IRB webmaster, Bill Altermatt, at altermattw@hanover.edu, or the chair of the Hanover College Institutional Review Board, Dean Jacks, at jacks@hanover.edu.

Appendix III

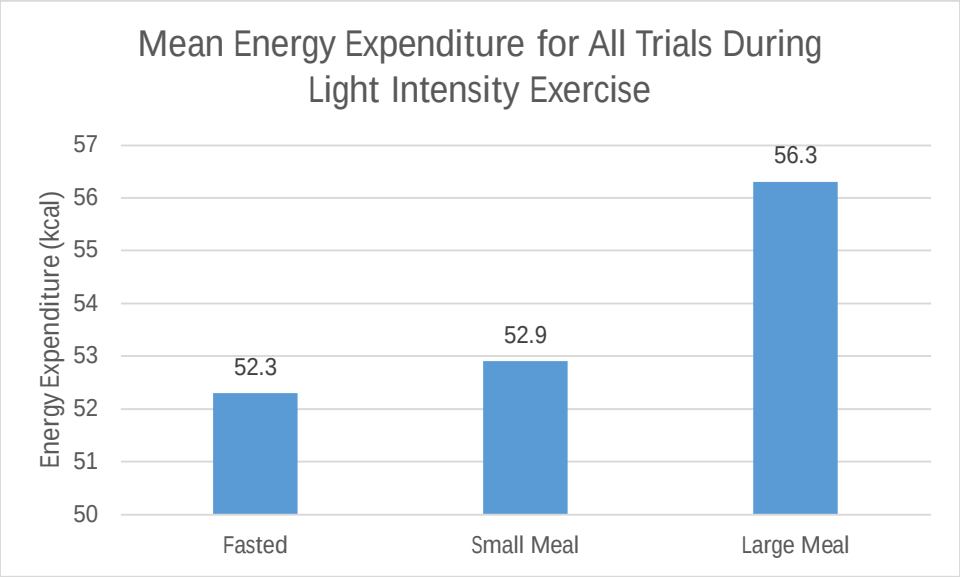


Figure 1. Displays the mean energy expenditure (kcal) for the fasted, small and large trials during light intensity exercise.

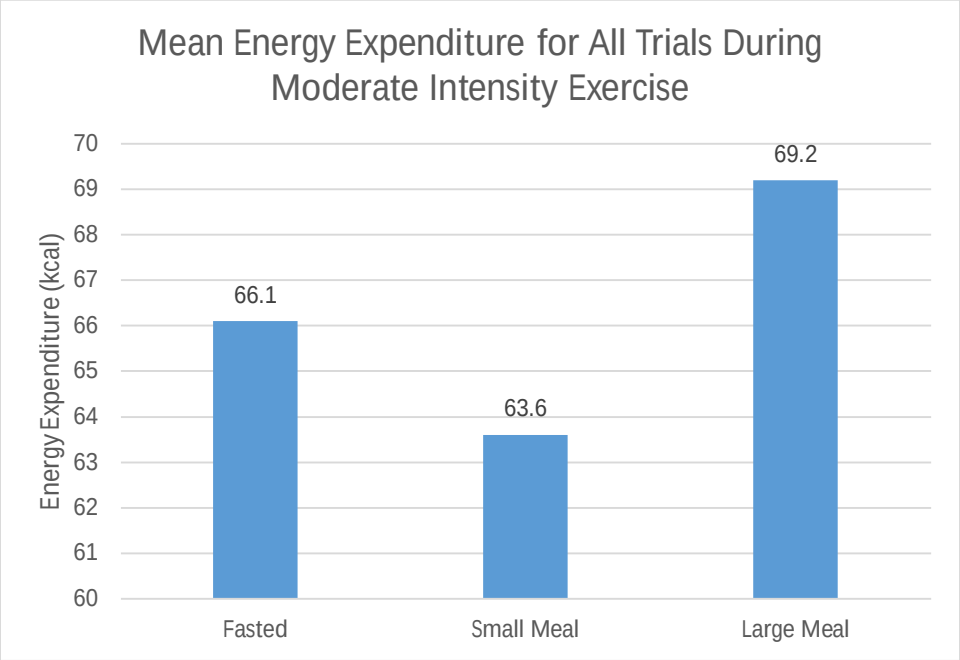


Figure 2. Shows the mean energy expenditure (kcal) for the fasted, small and large trials during moderate intensity exercise.

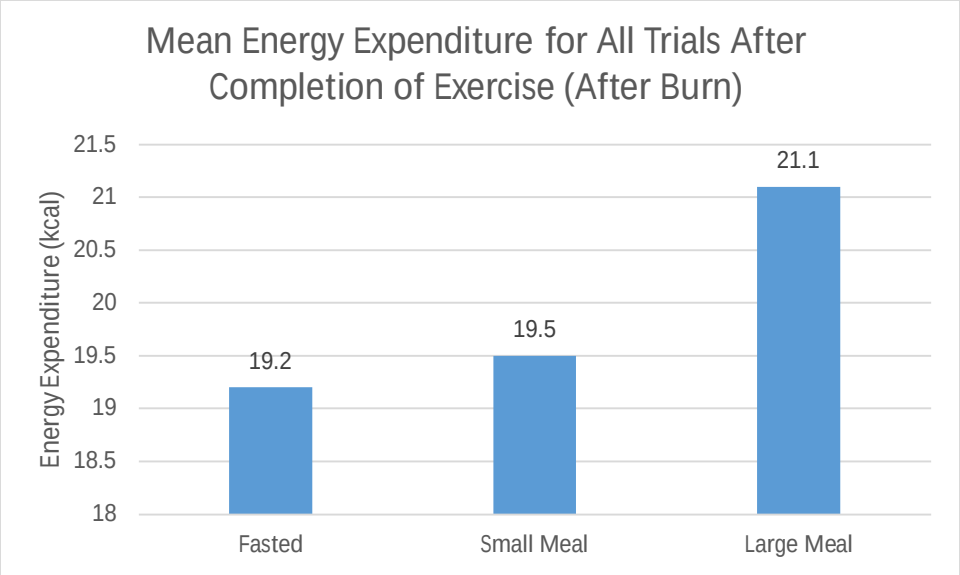


Figure 3. Displays the mean energy expenditure (kcal) for the fasted, small and large trials during the after burn period.