Evidence supports that participation in structured exercise may lead to compensatory increases in energy intake (EI) and/or decreases in energy expenditure (EE) that can reduce or eliminate the weight management benefits of exercise. Twenty college-aged males and females volunteered for an 8-week, 150 min/week walking or jogging physical education class. Average daily EI and EE were measured using 24-hr diet recall and accelerometry at three time points during the intervention. Average daily EE and EI were not significantly different among the three time periods ($p = .23$, $p = .52$, respectively) or between genders or exercise intensities. Baseline body fat was negatively correlated with changes in EE and EI ($r = -.40$, $r = -.36$, respectively). High variability in changes in EE and EI suggests that compensation varies substantially across individuals. Further research can strengthen these findings and influence modifications to weight loss programs to account for compensation.

INDEX WORDS: compensation, energy intake, energy expenditure, weight loss, exercise, physical activity, diet
PHYSICAL ACTIVITY AND DIET COMPENSATION IN RESPONSE TO A STRUCTURED EXERCISE PROGRAM

by

AMANDA DIANE GIPSON

B.A., Purdue University, 2010

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2012
DEDICATION

I would like to dedicate my thesis to my wonderful fiancé, family, and friends. When I came to Georgia, my life wasn’t what I expected. I had been close to home for so long and I was finally completely on my own 700 miles away. When I accepted the offer to attend graduate school at UGA, I didn’t know I would be leaving a boyfriend behind in Indiana. That definitely added a challenge to my life – trying to be a graduate student and maintain a long-distance relationship. Well, the end is now here and my boyfriend has become my fiancé. During the last two years, I could have never asked for a better support system than my family and friends. Zach, thank you for your unwavering support, encouragement, and sympathy. You deserve a fiancé of the year award! Mom, thank you for pushing me to pick myself up, dust myself off, and keep trying. As much as I wanted to throw myself a pity party at times, you wouldn’t let me. You kept me strong. Dad, thank you for giving me the hope and strength I needed to pull through successfully. To everyone that provided me with a boost when I was down or words of wisdom when I couldn’t think of any for myself: I wouldn’t be where I am today without you.
ACKNOWLEDGEMENTS

Obtaining my Master’s at the University of Georgia has turned out to be not only an enormous accomplishment, but also an extraordinary learning experience. I’d like to thank Dr. Schmidt, Dr. Evans, and Dr. O’Connor for serving on my committee and providing invaluable support and assistance on this project. I’d also like to thank my fellow graduate students for their tremendous encouragement over the last two years.
# TABLE OF CONTENTS

ACKNOWLEDGEMENTS........................................................................................................... v

LIST OF TABLES......................................................................................................................... ix

LIST OF FIGURES ...................................................................................................................... x

CHAPTER

1 INTRODUCTION ....................................................................................................................... 1

   Statement of Purpose ........................................................................................................ 3

   Hypotheses ......................................................................................................................... 3

   Significance ........................................................................................................................ 3

   Delimitations ...................................................................................................................... 4

   Limitations ........................................................................................................................ 4

   Assumptions ..................................................................................................................... 5

   Definition of Terms .......................................................................................................... 5

2 LITERATURE REVIEW ......................................................................................................... 6

   Obesity ............................................................................................................................... 6

   Physical Activity Recommendations ............................................................................. 7

   Weight Management ........................................................................................................ 10

   Individual Variability in Weight Loss Programs ......................................................... 12

   Compensation .................................................................................................................. 14
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>METHODS</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Participants</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Recruitment</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Protocol</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Exercise Intervention</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Testing and Data Collection Procedures</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Data Analyses</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>RESULTS</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Subjects</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Quantification of Exercise</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Comparison of Generalized and Regression Equations</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Dietary Compensation</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Activity Compensation</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Compensatory Responses between Genders</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Impact of Body Composition on Compensation</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Effect of Exercise Intensity on Compensation</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Relationship between Energy Intake and Energy Expenditure</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Weight Change</td>
<td>55</td>
</tr>
</tbody>
</table>
DISCUSSION ........................................................................................................... 58

Strengths .................................................................................................................. 62

Limitations ................................................................................................................ 62

Future Directions ..................................................................................................... 66

Conclusions ............................................................................................................... 67

REFERENCES ........................................................................................................... 68

APPENDICES

A INFORMED CONSENT ......................................................................................... 77

B FLYER ................................................................................................................... 80

C SCREENING MATERIALS .................................................................................... 81

D PEDB 1990 ENROLLMENT REPORT ................................................................. 87
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Healthy People 2020 Physical Activity Objectives</td>
<td>8</td>
</tr>
<tr>
<td>Table 2</td>
<td>Accelerometer Cut Points</td>
<td>22</td>
</tr>
<tr>
<td>Table 3</td>
<td>PWC-170 Protocol</td>
<td>31</td>
</tr>
<tr>
<td>Table 4</td>
<td>Treadmill Calibration Test Protocol</td>
<td>33</td>
</tr>
<tr>
<td>Table 5</td>
<td>Subject Characteristics at Baseline</td>
<td>43</td>
</tr>
<tr>
<td>Table 6</td>
<td>Comparison of EI across Intervention</td>
<td>46</td>
</tr>
<tr>
<td>Table 7</td>
<td>Comparison of EE across Intervention</td>
<td>48</td>
</tr>
<tr>
<td>Table 8</td>
<td>Changes in EE and EI by Gender</td>
<td>50</td>
</tr>
<tr>
<td>Table 9</td>
<td>Changes in EE and EI by Exercise Intensity</td>
<td>54</td>
</tr>
<tr>
<td>Table 10</td>
<td>Weight Change from Baseline to Week 5</td>
<td>56</td>
</tr>
<tr>
<td>Table 11</td>
<td>Weight Change from Baseline to Week 8</td>
<td>57</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Illustration of Energy Balance</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Testing and Data Collection Protocol</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>Average Moderate and Vigorous Activity Performed in Class</td>
<td>45</td>
</tr>
<tr>
<td>4</td>
<td>Comparison of Regression Equations to Generalized Equations</td>
<td>45</td>
</tr>
<tr>
<td>5</td>
<td>Distribution of Changes in EI from Baseline to Week 8</td>
<td>47</td>
</tr>
<tr>
<td>6</td>
<td>Distribution of Changes in EE from Baseline to Week 8</td>
<td>48</td>
</tr>
<tr>
<td>7</td>
<td>Energy Expenditure across Class Periods, by Gender</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>Energy Expenditure across Class Periods Controlled for Body Weight, by Gender</td>
<td>50</td>
</tr>
<tr>
<td>9</td>
<td>Correlation of Baseline Body Fat and BMI with Change in Average Daily EE from Baseline to Week 8</td>
<td>51</td>
</tr>
<tr>
<td>10</td>
<td>Correlation of Baseline Body Fat and BMI with Change in Average Daily EI from Baseline to Week 8</td>
<td>52</td>
</tr>
<tr>
<td>11</td>
<td>Energy Expenditure by Class Period</td>
<td>53</td>
</tr>
<tr>
<td>12</td>
<td>Energy Expenditure by Class Period Controlled for Body Weight</td>
<td>53</td>
</tr>
<tr>
<td>13</td>
<td>Relationship between EE and EI from Baseline to Week 8</td>
<td>54</td>
</tr>
<tr>
<td>14</td>
<td>Expected Weight Change Versus Actual Weight Change</td>
<td>55</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

Obesity currently affects one-third of Americans\(^1\) and is linked to cardiovascular disease risk factors, diabetes, and several forms of cancer.\(^2\) Since the prevalence of both obesity and its associated risk factors is growing, it is an issue that has yet to be resolved. Weight gain is caused by a positive energy balance related to energy intake (EI) exceeding energy expenditure (EE).\(^3\) The expectation of individuals undergoing a weight loss program is that, if EE is increased, a negative energy balance will lead to successful weight loss.

Many interventions aim to discover the best approach to help individuals lose weight using an exercise regimen, but the results are not equivalent for all participants. Inter-individual variability is apparent in exercise programs with some surpassing the expected weight loss and others unexpectedly gaining weight. A review of nine randomized controlled trials and 22 nonrandomized trials in 2001 suggested that average weight loss through structured exercise programs is only 30% of the predicted weight loss.\(^4\) The inadequacy of these weight loss programs lies mainly in the two main potential barriers to weight loss through exercise: compensatory metabolic adaptations and behavioral changes. Metabolic adaptations are automatic and usually very small, such as a decrease in resting metabolic rate.\(^5\) Behavioral changes are usually volitional and may be more likely to impair weight loss success than any metabolic changes. These behavioral changes can occur as an increase in EI or a decrease in EE, which can both be detrimental to weight loss.
Literature suggests that the magnitude of compensation that occurs can vary by sex, body composition, and exercise intensity.\textsuperscript{6-9} Experimental studies have shown gender differences in EI following an acute exercise bout.\textsuperscript{8} Energy intake ad libitum was measured in women following a control session, a low-intensity exercise session, and a high-intensity exercise session on three separate days. Women were found to have the highest EI following the high-intensity exercise bout.\textsuperscript{8} Following similar sessions, studies have shown that men do not change EI.\textsuperscript{9} Evidence shows that, after a 3-day exercise program, normal weight and obese individuals respond differently.\textsuperscript{7} Subjects were given food options from a vending machine and told to eat ad libitum. Normal weight individuals increased 6-day EI, while obese individuals did not change EI.\textsuperscript{7} The reason for this may be due to the ability of normal weight individuals to regulate body weight more effectively than obese individuals by altering EI to regain energy balance.\textsuperscript{7} The impact of exercise intensities on the compensatory response has also been examined and results suggest that high intensity exercise may lead to greater diet compensation than low or moderate exercise intensities.\textsuperscript{6} It has been suggested by previous literature that physiological mechanisms regulate body weight at a predetermined level; greater alterations to energy balance may trigger these mechanisms to return the body to a balanced level.\textsuperscript{10}

Several studies have examined compensation as an increase in EI, a decrease in Non-Exercise Activity Thermogenesis (NEAT), or both. However, there are differences among these studies in regards to the method of compensation measurement, the population examined, and the type and duration of exercise completed. Accelerometry and diet recalls will be used in this study to quantify activity and diet throughout the intervention period. Very few studies target college-aged men and women for physical activity outcomes, which will be the predominant
population for the current study. Also, the magnitude of compensation by changing EI or EE as a function of gender, body composition, and exercise intensity will be examined.

**Statement of Purpose**

The purpose of this study was to quantify the compensatory changes in EI and EE that occur among college-aged males and females in response to adding 150 minutes a week of structured exercise. Specifically, the magnitude of changes in EI and EE were compared between men and women, normal weight and overweight individuals, and moderate and vigorous exercise intensities.

**Hypotheses**

Prior to conducting this study, the following hypotheses were proposed:

1. Average daily EI would increase in response to the exercise program.
2. Average daily EE would decrease as a result of the intervention.
3. Women would increase EI and decrease EE more than men.
4. As body fat percentage increased, the magnitude of the compensatory response by both EI and EE would be attenuated.
5. The mixture of moderate and vigorous intensity exercise would lead to greater EI and EE compensation than moderate intensity exercise.

**Significance**

The outcomes of this study may be useful towards further research in the area of compensation. Simultaneously examining EE and EI in response to an exercise program can provide insight into the compensatory responses to exercise, in contrast to prior studies that have examined only one side of the energy balance equation. For example, there may be individuals
who compensate with food, but not with activity, or vice versa. The knowledge that people respond to exercise with different behavior changes might be beneficial for weight loss programs, as they will be able to target how certain people compensate. This study will determine the extent to which gender, baseline body composition, and exercise intensity influence the magnitude of compensatory responses to the addition of an exercise program. The disparities among individuals in similar weight loss programs with an exercise component will be minimized if steps can be taken to help individuals avoid compensatory responses to the program.

**Delimitations**

1. Subjects voluntarily chose to participate in the PEDB 1990 course.
2. Subjects were limited to students at The University of Georgia.
3. All subjects were between the ages of 18 and 30.

**Limitations**

1. A small sample size and specific target population lead to limited generalizability.
2. 24-hour diet recall provided limited precision of EI as the results rely on the subjects providing honest and accurate diet information and the ability of the software to appropriately analyze the information.
3. When examining lifestyle activities, especially those that involve limited trunk movement, there is imprecision in the quantification of activity EE by accelerometer.
4. The use of individualized regression equations to estimate EE from accelerometry risks the addition of measurement error compared to the generalized equations.
5. Intervention physical activity of 120 minutes a week is lower than the minimum activity recommendation for adults, which may not have been enough to lead to compensation.

**Assumptions**

1. Students provided honest, comprehensive information on the diet recall.
2. Subjects wore their assigned accelerometer as instructed, on the right hip midline with the right thigh, during all waking hours.
3. A minimum of 8 hours/day, 4 days a week of accelerometer wear time is representative of the subjects’ 7-day activity.
4. All subjects, at rest, consume 3.5 ml/kg/min of oxygen.

**Definition of Terms**

Compensation: The automatic metabolic (e.g. decrease in resting metabolic rate) and/or volitional behavioral (e.g. increase in energy intake, decrease in NEAT) adaptations that occur in response to a perturbation in energy balance.

Energy Intake (EI): In this context, amount of kilocalories consumed per day.

Energy Expenditure (EE): Dissipation of energy from the body through physical activity (voluntary movement; includes NEAT), resting metabolic rate (biochemical processes which produce heat) and thermic effect of feeding (energy cost of digestion of food); also measured in kilocalories.

Non-Exercise Activity Thermogenesis (NEAT): Energy cost of daily activities outside of the exercise program (includes but is not limited to: fidgeting, household chores, occupational physical activity).
CHAPTER 2

LITERATURE REVIEW

There are gaps in the current literature in regards to compensation that need to be addressed in additional research. These gaps will be examined in more detail in this literature review. The obesity epidemic as well as physical activity recommendations to combat the epidemic will be discussed. The effect of compensation on weight loss as well as the differences between groups will be examined.

Obesity

A growing number of U.S. Americans become overweight or obese each year. According to the 2007-2008 National Health and Nutrition Examination Survey, an estimated 34.2% of adults age 20 and over are overweight, 33.8% are obese, and 5.7% are extremely obese.\(^1\) Obesity is rarely an isolated health condition; it is linked to many comorbidities such as type II diabetes mellitus, hypercholesterolemia, and hypertension.\(^2\) In addition, overweight men age 40-65 have a 72% increased risk for coronary heart disease.\(^11\) The prevention and treatment of obesity improve body shapes, but, more importantly, are critical to population health.

Body mass index (BMI) is a clinical measure used to classify individuals into different weight categories (i.e. normal weight, overweight, obese).\(^12\) The BMI is calculated by dividing the individual’s weight in kilograms by the square of height in meters. An elevated BMI (>25 kg/m\(^2\)) that would classify an individual as overweight is associated with increased prevalence of the comorbidities associated with obesity. As BMI increases, the prevalence of the comorbidities
also increases. A cross-sectional study illustrated this relationship in 16,844 American adults. Increasing degrees of overweight and obesity were associated with an increased prevalence for a number of health outcomes: type II diabetes, gallbladder disease, coronary heart disease, and high blood pressure. High total cholesterol was more prevalent for those with a BMI $\geq 25$ kg/m$^2$, but did not increase with increasing weight status. The prevalence of two or more conditions also increased with worsening weight status. Modest weight loss of even just 5-10% of body weight can lead to decreased triglycerides, increased high-density lipoproteins (good cholesterol), and improvements in the oxidizability of lipids and lipoproteins.

**Physical Activity Recommendations**

Every 10 years, new physical activity goals are set by the collaborative efforts of the individuals who comprise the Healthy People Consortium. These individuals, who are from various colleges, universities, private businesses, and religious organizations, develop health and wellness goals for Americans. Healthy People 2020 includes goals for both adults and children (Table 1).

In addition, more specific recommendations were made by the Physical Activity Guidelines Committee and accepted by the Secretary of Health and Human Services in 2008. These guidelines provide detailed recommendations for weekly physical activity. The current recommendation for adults is 150 minutes a week of moderate intensity activity, 75 minutes of vigorous intensity activity, or an equivalent mix of moderate and vigorous intensity activity. Muscle strengthening activities on at least 2 days of the week is also recommended. Physical Activity Guidelines for Americans recognized that any amount of physical activity is preferred to none, but increasing amounts of physical activity produces greater health benefits.
### Table 1

*Healthy People 2020 Physical Activity Objectives*[^16]

<table>
<thead>
<tr>
<th>Population</th>
<th>Objective</th>
</tr>
</thead>
</table>
| Adults              | • Reduce proportion who participate in no leisure-time physical activity (PA)  
                      | • Increase proportion who meet current PA requirements                                                                                       |
| Adolescents         | • Increase proportion who meet current PA requirements  
                      | • Increase proportion of schools that require daily physical education and students who participate  
                      | • Increase regularly scheduled recess and proportion of schools that require/recommend recess  
                      | • Increase proportion who do not exceed recommended limits for screen time  
                      | • Increase number of states with licensing regulations for PA in child care  
                      | • Increase proportion of schools who provide access to physical activity spaces and activities outside of school hours  
                      | • Increase proportion of employed adults who have access to and participate in employer-based PA facilities and programs. |
| Adults & Children   | • Increase proportion of physician office visits that include education related to PA  
                      | • Increase number of trips made by walking and bicycling  
                      | • Increase legislative policies for environment that enhance access to and participation in PA |

To further emphasize the benefits of physical activity, the evidence of improved health related to exercise will be described. As stated by Pate et al., several studies show that relative risk of cardiovascular mortality decreases with increasing participation in physical activity.[^17]

Furthermore, evidence shows exercise provides an individual with some amount of protection against coronary heart disease, hypertension, type II diabetes, osteoporosis, colon cancer, anxiety, and depression.[^17] It is estimated by Hahn and McGinnis that lack of exercise contributes to approximately 12% of the total yearly deaths in the U.S.[^18][^19] Furthermore, exercise training can lead to improvements in maximal oxygen uptake, decreased myocardial oxygen demand, increased high-density lipoproteins (good cholesterol), improved insulin sensitivity, strengthened muscles, increased aerobic endurance, and decreased risk of cardiovascular disease.[^20] A review

[^16]: Healthy People 2020 Physical Activity Objectives
[^17]: Pate et al.
[^18]: Hahn and McGinnis
[^19]: Hahn and McGinnis
[^20]: A review
of 47 clinical trials indicated reductions with exercise of 4% and 5% in systolic and diastolic blood pressure, respectively, in hypertensive subjects and reductions of 2% and 1% in systolic and diastolic blood pressure, respectively, in normotensive subjects.21

It has been established that exercise produces beneficial health-related changes, and to supplement that, exercise can be used alone as a path to weight loss. An example of the success of an exercise-induced weight loss program is a randomized-controlled trial by Ross et al. in 2000. Fifty-two overweight men were randomly assigned to one of four groups: control, diet-induced weight loss, exercise-induced weight loss, or exercise without weight loss. Both weight loss groups were asked to produce a deficit of 700 kcals/day; the diet-induced weight loss group did so by reducing caloric intake and the exercise-induced group expended 700 kcals/day by exercising while maintaining their diet. The heart rate recorded during the exercise session and the results of a fitness test were used together to estimate the energy expenditure (EE) of exercise. As a result of the intervention, the two weight loss groups lost similar amounts of weight (an average of 7.4 kg and 7.6 kg, respectively) during the 12-week period.22 This study provides evidence that exercise can be an effective way to lose weight if enough exercise is performed and caloric intake is held constant.

Blair reviewed weight loss studies to determine the effectiveness of exercise in weight loss success and found that exercise is beneficial when added to a program of caloric restriction, although it’s added effects are small.23 In addition, evidence supports exercise as a contributor to the long-term maintenance of weight loss. Furthermore, regardless of weight status, active individuals are less likely to suffer from morbidity or mortality than sedentary individuals.
Weight Management

Weight maintenance occurs when the body is in a state of energy balance, meaning energy intake (EI) is equal to EE (Figure 1). Energy intake is simply the calories that are consumed. Energy expenditure is a combination of basal metabolic rate, thermic effect of feeding, non-exercise activity thermogenesis (NEAT) and the energy cost of exercise. Weight loss is achieved by driving the body into a state of negative energy balance of expending more calories than are consumed. A negative energy balance can involve maintaining EE while decreasing EI (diet-induced weight loss), increasing EE while maintaining EI (exercise-induced weight loss), or increasing EE while decreasing EI (diet and exercise-induced weight loss).^5

<table>
<thead>
<tr>
<th>Energy Intake</th>
<th>Energy Expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basal Metabolic Rate</td>
</tr>
<tr>
<td></td>
<td>+ ThermicEffect of Feeding</td>
</tr>
<tr>
<td></td>
<td>+ Non-Exercise EE (NEAT)</td>
</tr>
<tr>
<td></td>
<td>+ Exercise EE</td>
</tr>
</tbody>
</table>

Figure 1. Illustration of Energy Balance

A descriptive study of 629 women and 155 men reported the characteristics of individuals successful at weight loss and the methods that were most widely used in their weight loss efforts. The most popular weight loss method, reported by 89% of the sample, was diet and physical activity modification. Only 10% of the participants used diet modification alone and only 1% used physical activity alone.^24

According to guidelines by the Institutes of Medicine, the appropriate weight loss program
for the individual should be chosen based on 3 criteria: matching the program to the individual, program safety, and program outcomes. The program should be tailored to achieve the necessary amount of weight loss. For instance, a person who is 20% overweight would not need weight loss surgery, but would need to change EI or EE to induce weight loss. For instance, a deficit of 7700 kcals/week would lead to 1 kg of weight loss, and this can be achieved by increasing EE, decreasing EI, or both. Risk of disease is also a deciding factor for the correct weight loss program. In addition, people who are severely obese may not benefit from an unsupervised program while someone who is overweight may succeed using the same approach. To ensure safety, weight loss programs should provide a health and psychological assessment to avoid these factors further negatively affecting a person’s health and well-being. These programs should address appropriate amounts and types of exercise as well as food quality and macronutrient intake. Individuals should also be given the necessary tools to maintain the weight loss achieved from participation in the program. The goal of a weight loss program is always to lose weight, but it should also be to maintain the weight loss and health benefits.

The American College of Sports Medicine produced a position stand on physical activity for weight management. There is evidence that adding physical activity to a calorie restrictive program will increase weight loss, but this effect will diminish with greater amounts of caloric restriction. Resistance training will not lead to clinically significant weight loss, although there are other benefits of this type of exercise as mentioned previously (i.e. maintenance of fat-free mass through weight loss). The Institute of Medicine reported evidence that physical activity may help prevent weight gain after weight loss. More specifically, 150 to 250 minutes a week of moderate intensity physical activity should aid in the prevention of weight gain.
Weight loss can occur using any of the aforementioned methods; however, some are evidenced to be more beneficial than others. For example, Miller et al. compiled results of 493 weight loss studies that included diet only, exercise only and diet and exercise interventions.\textsuperscript{29} Amount of weight lost was similar between the diet only and diet and exercise groups at an average of 10.7 kg and 11.0 kg, respectively. The exercise only group lost only an average of 2.9 kg. The average amount of fat lost was greatest for the diet and exercise group (average = 9.0 kg). The diet only group lost an average of 7.8 kg of fat while the exercise only group lost 3.3 kg of fat. The results of this review conclude that the most effective method of weight loss would include a diet intervention and added exercise would improve the results further.

A meta-analysis by Ballor and Poehlman examined the effect of adding exercise to a diet intervention on preservation of fat-free mass.\textsuperscript{30} The diet only and diet plus exercise groups lost similar amounts of weight (average = 10 kg) and fat mass (average = 8 kg). The amount of fat-free mass lost differed between groups with the exercise in the diet plus exercise group leading to an attenuation of the loss of fat-free mass. The diet plus exercise group lost only about half of the fat-free mass lost by the diet only group (28\% vs. 13\% among males; 24\% vs. 11\% among females). This evidence supports the addition of an exercise program to a weight-loss program to maintain fat-free mass. Higher body fat is associated with higher cardiovascular disease risk, so maintaining fat-free mass through weight loss will aid in lowering risk of disease.\textsuperscript{31}

\textbf{Individual Variability in Weight Loss Programs}

Weight loss programs always aim to create a sustained negative energy balance, whether by adding exercise, limiting EI, or both, but the participants do not always achieve this sustained energy deficit. For example, a study done by Manthou et al. indicated that the addition of 150
minutes a week of aerobic exercise did not lead to equal responses among all participants as far as the amount of fat lost. Overweight or obese women (n=34) participated in an 8-week intervention that involved 150 minutes a week of cycle ergometry at 72-77% of age-predicted heart rate maximum. Physical activity was recorded in a 24-hour physical activity diary for the 7 consecutive days prior to the start of the intervention and during week 8 of the intervention. Researchers used 24-hour physical activity diaries to calculate daily EE. Resting metabolic rate was also measured, which allowed the researchers to determine net exercise EE. As a group, these women experienced no significant fat loss. When examined individually, it was found that some individuals lost more than or the same as the expected fat loss (responders) or less fat than expected (non-responders). Looking at the results as a group masked the individual differences that occurred. All of the study participants completed 100% of the exercise sessions, so other factors must be responsible for causing this individual variability in response. It was observed that average total EE increased more for the responders (+343.9 kcals) than the non-responders (+69.3 kcals) and average activity EE (NEAT) increased for the responders (+188.7 kcals) but decreased for the non-responders (-148.1 kcals). The decrease in NEAT and the attenuation of the increase in total EE may have been large enough to negate the EE of the exercise itself among some individuals. From what is known about energy balance, it can be concluded that, even though one component of EE increases, it doesn’t necessarily lead to an increase in total EE. If a component of EE decreases in response to the increase of another, there may end up being no net increase in total EE and therefore no weight loss.

Like Manthou, Church et al. conducted a study examining the variability in individual responses to an exercise program. There were 411 female, post-menopausal participants with a
mean age of 57 and a mean weight of 84.2 kg. Subjects were randomized to groups with varying doses of exercise: a control group (no exercise), a 4 kcal/kg/week group, an 8 kcal/kg/week group, or a 12 kcal/kg/week group. Pedometers were worn throughout the 6-month intervention period to measure potential changes in daily activity. All participants were told that the intervention was not part of a weight loss study and that they should not change their usual habits and lifestyle. The results of this study assessed the participants’ weight response to the addition of an exercise program. All groups significantly decreased weight from baseline values and there was no difference in the amount of weight lost between the groups. Expected weight change was estimated based on the amount of kilocalories used during the exercise sessions. The participants’ actual weight change was compared to the predicted weight change; the actual weight change for all groups was similar to the predicted values except for the 12 kcal/kg/week group who lost an average of 1.2 kg less than expected. The researchers concluded that increasing intensities of exercise might lead to a larger discrepancy between expected and actual weight loss. The most plausible reason for this occurrence is that a compensatory increase in EI led to weight gain in some individuals. When split into groups based on weight change, those that lost weight had an average EI of 1766 kcals/day at follow-up while those that maintained or gained weight had an average EI of 2035 kcals/day.

**Compensation**

When an individual begins an exercise program, the perturbations to energy balance may cause adaptations to occur that affect total EE. For example, basal metabolic rate may decrease in an effort to maintain the usual daily EE. Since this particular adaptation appears to be small relative to total EE, it is not likely the reason individuals do not lose the expected amount of
weight. Behavioral adaptations may also occur for some individuals in response to an exercise program. These changes are usually volitional and may occur as an increase in EI or a decrease in EE. Because of these behavioral compensatory responses, the effectiveness of exercise interventions may be weakened for some individuals.

Research has shown that compensation may be a large contributor to the failure of weight loss efforts among some individuals. King et al. examined this concept through a 12-week exercise program for 35 overweight men and women that aimed to expend 500 kcal per session, 5 days a week. The subjects chose from a selection of exercise machines that included cycle ergometers, treadmills, stepping machines, and rowing ergometers and exercised at an intensity of 70% of heart rate maximum. The group as a whole lost an average of 3.7 kg, but there was substantial variability between subjects with the changes in weight ranging from -14.7 kg to +1.7 kg. Just as in the Manthou study, the group was split into compensators, who lost less weight than predicted, and non-compensators, who lost equal to or more than predicted weight. The exercise EE was measured during each session to confirm that all subjects were performing the same amount of activity and there was no significant difference between the compensators and non-compensators. Subjects were given test meals for lunch and dinner on the morning of weeks 0 and 12. Subjects chose their own meals and ate until they were comfortably full. The meals were the same for weeks 0 and 12. Energy intake at week 0 increased for compensators by an average of 268.2 kcal compared to week 12 EI, while the non-compensators decreased EI by an average of 130.0 kcal from week 0 to week 12. This suggests that the compensators may not have reached the predicted amount of weight loss due to a compensatory increase in EI. The
previous study is an example of compensation by increasing EI. The next example will provide evidence of compensation by decreasing EE.

Colley et al. conducted an 8-week walking intervention that expended 1500 kcal each week. The first 4 weeks were supervised and the second 4 weeks were unsupervised. The subjects wore an accelerometer at baseline and for 14 consecutive days during weeks 3 and 4 in order to determine time spent in sedentary, light, moderate, and vigorous physical activity. Total EE was measured by doubly-labeled water during the time the accelerometers were worn and resting metabolic rate was measured. The thermic effect of feeding was assumed to be 10% of total EE. At the end of the intervention, total EE, resting metabolic rate, and thermic effect of feeding were unchanged even with the addition of an exercise program. Daily exercise EE started at 0 kcal/day and increased to an average of 173 kcal/day by the end of the intervention. However, this structured exercise did not increase total EE because there was a compensatory decrease in NEAT by 175 kcal/day.\(^3\)

**Factors Influencing Compensatory Responses**

Some studies have compared compensatory responses based on several different variables. More specifically, the magnitude of compensation related to gender, exercise intensity, and body weight will be examined. Existing evidence suggests that women and men may behave differently in response to an exercise session. For example, it has been observed that, after an acute exercise bout, men do not change subjective levels of hunger and fullness or EI.\(^9\) A study by Thompson et al. demonstrated this by subjecting 15 college-aged males to 3 different conditions: no exercise control, cycling at 35% \(\text{VO}_{2\text{max}}\), and cycling at 68% \(\text{VO}_{2\text{max}}\). The two exercise sessions aimed to expend 4.1 kcals/kg body weight, so there was no set exercise
duration. The subjects were given a test meal 1 hour post-exercise. There was evidence of suppressed hunger after the higher intensity exercise session as compared to the low intensity exercise, but EI was stable in all 3 conditions. A similar study by Imbeault et al. showed comparable findings. Eleven male subjects participated in three randomly assigned conditions: control, treadmill walking at 35% VO$_{2max}$, and treadmill running at 75% VO$_{2max}$. Both exercise sessions expended around 489.8 kcals. Subjects were given a buffet type meal after each session where they were instructed to eat *ad libitum*. No significant difference was found in EI between the two exercise sessions, although EI was higher after the lower intensity exercise compared to the control session.

A similar study in women showed largely different results. Thirteen women participated in three sessions similar to the previously mentioned studies in males: control, 40% VO$_{2max}$, and 70% VO2max. An expenditure of 350 kcals was attained from each of the exercise bouts. Following each session, the women were exposed to a buffet and told to eat *ad libitum*. Average absolute EI was greater after the high-intensity exercise session than the control session (high-intensity = 878 kcals and control = 751 kcals).

Mayer et al. examined whether weight status presents different responses to exercise in a mouse model. When 45 days of exercise was added to their originally sedentary lifestyle, non-obese mice increased EI proportionately to the EE of the daily exercise, ultimately leading to only a slight weight increase. (EI: +4.2 grams, Weight: + 2.8 grams). The obese mice also increased EI in response to the exercise, but this increase was attenuated in the exercise group compared to the non-exercise group. (Exercise group: EI: +7.0 grams, Weight: +9.2 grams; Non-exercise group: EI: +4.5 grams, Weight: +14.7 grams).
A similar finding in humans was reported by Durrant et al.\textsuperscript{7} Twelve obese and 4 lean subjects were recruited to participate in 3 consecutive exercise sessions that involved cycling at a self-selected pace to reach at least 1000 revolutions per session. The average EE for the lean and obese subjects was 118 kcals/day and 100 kcals/day, respectively. The individuals were provided the opportunity to obtain food from a vending machine in order to better estimate EI. Energy intake was monitored for 6 days: the three days that included exercise and the three days of no exercise. Surprisingly, lean individuals increased EI during the exercise period to an extent that it exceeded EE. Overweight individuals did not change dietary intake by a significant amount. The paradigm that lean individuals regulate body weight more accurately than overweight individuals would explain this unexpected finding. In order to maintain a stable weight, all subjects would need to increase EI; however, the lean subjects were able to regulate this while the obese subjects were not. The corollary to this may be that homeostatic set point for weight regulation is more easily threatened in normal weight individuals compared to obese individuals when the body is in an energy deficit state.\textsuperscript{10}

Regarding exercise intensity, the Church et al. study that was previously described provided subjects with varying degrees of exercise intensities: 4 kcals/kg/week, 8 kcals/kg/week, and 12 kcals/kg/week. The researchers found that the highest intensity group lost less than the predicted weight while the remaining groups achieved the predicted weight loss.\textsuperscript{6}

Another study mentioned previously by Pomerleau et al. examined compensatory responses in women.\textsuperscript{36} The women participated in three different sessions: a control session involving no exercise, a session at 40\% of VO\textsubscript{2peak}, and a session at 70\% VO\textsubscript{2peak} with the exercise sessions being equicaloric to each expend 350 kcals. As described earlier, the subjects
were given a buffet-style meal after each session and told to eat ad libitum. The results suggest that higher intensity exercise will increase EI in women compared to lower intensity exercise or a non-exercise session. Studies have demonstrated that gender, body composition, and exercise intensity may influence compensatory responses to structured exercise.

**Measurement of Physical Activity**

The gold standard method of measuring free-living EE is doubly-labeled water. This method enables researchers to objectively measure cumulative CO₂ production over up to 7-14 days based on the rate of elimination of the ingested isotopes $^{18}$O and $^2$H from the body.$^{38}$ The doubly-labeled water method, although effective, is very costly and therefore was not an option for the present study.$^{39}$ In addition, this method only provides total EE and not estimates of activity intensity throughout the day.$^{39}$ This is an obstacle for anyone needing to measure free-living EE, necessitating the use of other objective methods such as heart rate monitoring and accelerometry. Continuous heart rate monitoring has been shown to measure within 10% of doubly-labeled water estimates of EE.$^{40}$ The use of heart rate monitoring to estimate free-living EE is also subject to error due to the variability of heart rate with alcohol, stress, medication, and caffeine, mathematical error because of large discrepancies between resting and activity heart rate, requires graded exercise testing of all participants, and is associated with greater subject burden than other available methods such as accelerometry.$^{41}$

Accelerometers are another objective method for measuring free-living activity as well as planned, structured exercise. Benefits of this tool are that they are small, non-invasive, and simple to upload and analyze. Unfortunately, though, the accelerometers are not very fashionable, they are not waterproof and therefore cannot capture any water-based activity,$^{42}$ and
have difficulty capturing some activities. Bourne et al. studied the relationship between body
accelerations as measured by a triaxial accelerometer and EE of the activity as measured by a gas
analyzer. It was found that there was a large amount of inter-individual variability during
sedentary activities such as sitting or sitting and writing. Less variability was found during
walking. Welk et al. examined Actigraph validity during treadmill walking and running as well
as lifestyle activities such as sweeping, vacuuming, and shoveling. The Actigraph correlated with
VO_{2} estimates of walking and running at r = 0.85, while correlating with lifestyle activities at r =
0.48. These results suggest the accelerometer to be a useful tool to measure all types of
activities, especially walking and jogging, which is the intervention activity for the present study.
Accelerometers may not be as accurate at measuring free-living activities because, as the monitor
is worn on the hip and only measures whole body movements, it is unable to capture changes in
incline, terrain, extra carried load or upper body movements.

Inter-instrument reliability is strong for the Actigraph uniaxial accelerometer with an
intra-class reliability coefficient of 0.80, but a coefficient of variation of 10%. Hendelman et al.
concluded from a field study that the Actigraph accelerometer strongly correlated with MET
values of activities (r = 0.77). It has been suggested that using multiple monitors may capture
EE more accurately, though it may not be provide enough benefit that the extra participant
burden would be justified. In adults, sufficient wear time to capture habitual physical activity is
around 3-5 days, but with differences between activity on weekdays and weekend-days, a 7-day
wear period is the most practical. A study that examined the best practice recommendations for
use of accelerometry in a physical activity intervention reiterated a finding from Trost et al. that
3-4 days of accelerometer wear is necessary for 80% reliability in the estimate of activity over a 7-day period.\textsuperscript{48}

For the purpose of estimating EE, there are generalized equations that are often integrated with the accelerometer software. These are simple and give a rough estimate of EE for the wear period. Freedson and colleagues developed these equations by collecting uniaxial accelerometer counts and oxygen consumption data during a 3-stage treadmill exercise protocol on 25 males and 25 females.\textsuperscript{49} METs were calculated for each stage of exercise by dividing steady state oxygen consumption during each stage by 3.5 ml/kg/min (resting VO\textsubscript{2}). Linear regression was performed on the average accelerometer counts and METs for each stage of exercise. Accelerometer cut-points were then created based on the intensity level that the accelerometer counts represented (Table 2). However, developing individualized prediction equations for each person may result in more precise estimates as it uses each subject’s own oxygen consumption value and accelerometer counts to generate the prediction equation. This method may improve precision, especially when attempting to detect small differences in EE over time.\textsuperscript{47} The generalized equations are based on a group and won’t account for individual differences in gait, efficiency, and fitness level. This method is frequently avoided because of the added researcher burden,\textsuperscript{47} as it requires an exercise test for each subject, additional data entry, and the application of each subject’s equation to their respective accelerometer files. Hendelman et al. developed individualized equations for their subjects based on walking at four different speeds. These equations were then used to predict MET values of several household and recreational activities. This method provided a 50% underestimation of MET value for gardening and housecleaning and a 30% underestimation for golfing and lawn mowing. The correlation between Actigraph
counts and MET value for walking alone was $r = 0.77$ while the correlation between Actigraph counts and all activities was $r = 0.59$. This may not be an issue with the equations, but rather a weakness of the monitor to accurately capture all types of activities.

Table 2

<table>
<thead>
<tr>
<th>Activity Intensity</th>
<th>Accelerometer Cut Points (counts/min)</th>
<th>METs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>760 - 1952</td>
<td>$&lt; 3.00$</td>
</tr>
<tr>
<td>Moderate</td>
<td>1953 - 5724</td>
<td>3.00 – 5.99</td>
</tr>
<tr>
<td>Vigorous</td>
<td>5725 - 9498</td>
<td>6.00 – 8.99</td>
</tr>
<tr>
<td>Very Vigorous</td>
<td>9499 +</td>
<td>$&gt; 8.99$</td>
</tr>
</tbody>
</table>

Measurement of Energy Intake

Energy intake can be most accurately measured in very controlled situations such as in a laboratory or clinic. The best way to truly know what a person ingests is to provide them with food of known composition and observe the amount that is eaten. This method is only useful if the researchers only need information about dietary intake while in the laboratory and there is little importance on habitual intake or food choices. Biological markers (which will equal EI in weight stable individuals) that reflect EI can also be used for this assessment, such as doubly-labeled water to measure EE and urinary nitrogen to measure protein intake. Because of high cost and participant burden, these markers are often used as a validation tool to assess other EI measurement methods.

Common field-based methods to assess EI often involve self-report and measure EI in free-living conditions rather than in a laboratory. Dietary records and dietary recalls are included in this category. Both records and recalls can be quantitative or qualitative and can describe foods by picture or household measures. Records can be logged by either the subject or a
researcher and should not require a subject to remember meals from past times. Recalls can require that a subject remember meals from a previous day or for an indefinite period of time. Both records and recalls can be converted to nutrient intake, if necessary.\(^{50}\)

For example, a 24-hour diet recall that uses an automated multiple pass method (AMPM) was recently developed by the National Cancer Institute. This free, web-based program provides individual-level nutrient estimates based on the Food and Nutrient Database for Dietary Surveys (FNDDS) as well as group estimates using the USDA’s MyPyramid Equivalents Database (MPED).\(^{51}\) A study by Blanton et al. included 20 women who participated in 14 days of free-living activities to assess EI by doubly-labeled water, AMPM 24-hour diet recall, food record, and food frequency questionnaire.\(^{52}\) The AMPM and food record measured the group EI within 4\% of the doubly-labeled water estimate. The questionnaire greatly underestimated the group EI by approximately 27\%. The AMPM method was moderately correlated (r = 0.53) with doubly-labeled water estimates unlike the other methods.

**Compensation as Measured by Accelerometry and Diet Recall**

Many Americans are overweight or obese which presents many health complications for those individuals. To reduce the risk and severity of health complications that often occur with obesity, weight loss and exercise are important. Weight loss programs are not effective for all participants as there is large variability observed through weight loss programs. Studies have found that, through weight loss and exercise interventions, some individuals compensate by increasing EI or decreasing EE to the extent that the benefits of the intervention are reduced or eliminated. In the present study, accelerometers objectively measured the daily activity and EE of the subjects and the ASA24 diet recall program gave comprehensive information regarding
the EI of the subjects. Energy intake and EE were both examined to determine where this compensation may be occurring and to what extent it occurs. Prior research suggests there may be differences in compensatory responses by gender, body composition, and exercise intensity. Accurate measurement of changes in EI and EE are required to more fully examine the factors that may influence compensatory responses to structured exercise. Accelerometers and multiple 24-hour recalls are two feasible approaches that have the potential to improve estimates of compensatory activity and diet changes.
CHAPTER 3

METHODS

Participants

The subjects that were targeted to join the study were college-aged students who were relatively sedentary. Subjects were included in the study if they met the following criteria: enrolled in PEDB (Physical Education Basic) 1990, willing to be randomized to either a walking or jogging exercise group, and between 18 and 30 years old. One credit of PEDB is required for all undergraduates at the University of Georgia, and PEDB 1990 is a course that was created as part of the physical education curriculum for the purpose of the research study. Within the PEDB 1990 course were two separate sections: the walking and jogging sections. To be included in the study, subjects had to be willing to be randomized to one of the two sections. Subjects were excluded if they had orthopedic limitations that inhibited ambulation, were pregnant or attempting to become pregnant, were lactating, or if they had a chronic health condition or took medication that affected participation in physical activity or influenced diet. The incentives for remaining in the study included one credit hour for PEDB upon proper completion of the course and a full-body Dual-Energy X-Ray Absorptiometry (DXA) scan. This study was approved by the Institutional Review Board and all participants signed an informed consent document (Appendix A) before any data collection procedures took place.
Recruitment

To begin recruitment, flyers (Appendix B) were created and posted in several campus buildings. In addition, postcard size versions of the same flyer were created and passed out to students walking around campus or in buildings on campus. Around 400 flyers total were either posted or handed out. A brief presentation was given to three Kinesiology department classes on campus and those students were also given flyers about the study. Finally, several campus advisors from various schools within the University of Georgia were asked to inform their students about the study.

Once the enrollment period began (October 21, 2011), students were able to register for PEDB 1990 as well as any other desired courses. On Oasis, the website for class registration, there was a short description of PEDB 1990 that was also used as a recruitment tool. The description read, “This is a research study evaluating behavior changes with structured exercise. Students will be randomly assigned to either a PEDB walking or jogging class. Contact researchers at uga.pe.study@gmail.com.” The roster was monitored closely and as new students registered they were sent a comprehensive e-mail that included the course syllabus, the screening form, and a brief e-mail message describing the study (Appendix C). This was meant to ensure the students understood the study demands and requirements.

During the “drop-add” period from October 21, 2011 to January 13, 2012, students were able to add and drop courses as they pleased. This presented difficulties as the number of students enrolled changed very often and it was difficult to keep up with the changing roster to e-mail materials to the new students. During the week before classes began enrollment was low, at around 25. At this point, recruitment was extended to the other physical education courses to
increase the number of subjects in the study. Instructors for other physical education classes were asked to send the recruitment e-mail that included the syllabus and screening form to their current students with a goal of recruiting additional participants. It is unknown how many of these instructors sent out the recruitment e-mail.

In total, 63 students registered for PEDB 1990 at some point during the registration period (October 21, 2012 – January 13, 2012). Of these 63 students, 24 attended the first class and signed the informed consent. Three of those 24 students dropped the course due to schedule conflicts, and 1 subject withdrew from the course due to health reasons unrelated to the course. Twenty subjects remained in the course and are included in the final analyses. The breakdown of subject enrollment can be seen in the Appendix D.

**Protocol**

PEDB 1990 was a 10-week course that met on Tuesdays and Thursdays for 75 minutes each day from January 9 to March 22, 2012. The first class period consisted mainly of subject familiarization to the study. The subjects were assigned their individual subject identification number (subject ID) which would serve as their primary form of identification for privacy purposes. All materials, forms, and equipment were labeled with their subject ID rather than their name. The schedule for the semester was reviewed with the students and they signed the informed consent. Students also signed up for three outside of class testing procedures (submaximal exercise test, calibration test, DXA scan) conducted during the first weeks of the study. At the conclusion of the class, subjects had height and weight measurements recorded and were each given an accelerometer that corresponded to their subject ID to wear for the week. The first round of the 3-day diet recall was also completed by the students during week 1. The
specific procedures for the accelerometer and diet recall will be discussed in detail in the Accelerometry and Diet Recall sections.

The second class period was devoted to the completion of the study questionnaires, which took most of the 75-minute class period to complete. Data from these questionnaires were utilized in a separate analysis and will not be further described here.

Before the second week of class, students were randomized to either a walking or jogging group. To randomly assign subjects, they were first classified into different groups based on BMI status (underweight = BMI < 18.5, normal weight = 18.5 < BMI < 24.9, overweight = 25 < BMI < 29.9, obese = BMI > 30). Each BMI group was then randomized to one group or the other using SPSS statistical software (IBM Corp., Armonk, NY). This allowed equal numbers of each weight classification in both groups. After randomization, the walking and jogging sections were comprised of 5 females and 5 males, and 8 females and 2 males, respectively.

The subjects participated in their assigned physical activity class each Tuesday and Thursday from weeks 2-9 of the class (8 weeks total). In order to measure the dose of physical activity performed during the class periods, the students wore accelerometers during each class. In addition to these measurements, free-living energy expenditure (EE) and energy intake (EI) were measured by accelerometry and diet recall, respectively, during weeks 1, 5, and 8. Weight was measured again during week 9 to assess any weight changes that occurred during the intervention. Follow-up measurements of body fat and fitness level were not completed. The testing and data collection schedule is displayed in Figure 2.
Exercise Intervention

The intervention consisted of either a 75-minute walking class or a 75-minute jogging class held twice weekly for 8 weeks. The walking class consisted of mostly moderate physical activity and the jogging class consisted of both moderate and vigorous physical activity. Each class period began with 5-10 minutes of administrative activities. As the students entered the gym, attendance was tracked and accelerometers were handed out. This routine was followed each class except for those during weeks 1, 5 and 8, as the students wore their accelerometers to class on those days. Following the administrative tasks, physical activity began with a few minutes of dynamic stretching immediately followed by the walking or jogging route for the day. After about an hour of activity, the students returned to the gym to log their activity for the day (miles completed and duration of activity) and to return their accelerometers.

Ten class periods were held on the indoor track within the Ramsey Center due to inclement weather. The students were led on an outdoor trail or on sidewalks through campus for the
remaining 5 class periods. The walking class was limited to only walking throughout the class period while the jogging class completed their routes by mostly jogging. Intermittent walk/jog routines were followed at the beginning of the semester by the jogging class as many students were not able to jog consistently for one hour. For instance, during one of the first activity classes, students jogged two laps, walked one lap and repeated this pattern throughout the 60 minutes.

**Testing and Data Collection Procedures**

**Physical Working Capacity-170 (PWC-170)**

The PWC-170 submaximal exercise test protocol was used to estimate the fitness level of participants at baseline. A pendulum-operated cycle ergometer (Monark Ergomedic 828E, Monark, Stockholm, Sweden) was used for the testing. The calibration of the cycle ergometers was inspected prior to their use to ensure that the load that was placed on the cycle was accurate.

The protocol that was followed was based on the subject’s heart rate response to the different workloads. The test involved 3, 4-minute stages of exercise with the goal of each stage being to reach a certain heart rate range. The workload of each stage was changed in order to induce a heart rate in a specific range (Table 3). A fourth stage was only necessary if a heart rate between 145-160 was not reached in the third stage. When the subjects arrived at the lab, they were fitted with a heart rate monitor (Polar Fs3C, Polar, Finland) and their blood pressure and resting heart rate were recorded. The protocol was explained to the subject and any questions were answered. They were then fitted to the bike prior to the start of the test. The test began with a warm-up at 0.5 kp for each subject even though the protocol recommends otherwise. During preliminary testing, it was noticed that even fit subjects responded with a heart rate within the
range of stage 1 during the warm-up. To avoid unexpectedly high heart rates in the beginning stages, the lowest workload was used during the warm-up. The subject’s heart rate as measured by the Polar FS3C Heart Rate Monitor was recorded at the end of each minute of exercise.

Table 3

<table>
<thead>
<tr>
<th>Stage</th>
<th>(HR goal)</th>
<th>Workload (kp)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>Warm-up</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>1</td>
<td>(HR&gt;115-130)</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>(HR&gt;130-145)</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>(HR&gt;145-160)</td>
<td>3</td>
</tr>
<tr>
<td>4 - if required</td>
<td>(HR&gt;145-160)</td>
<td>3.5</td>
</tr>
</tbody>
</table>

*use for overweight or very sedentary subjects

Linear regression of PWC-170 on VO₂max resulted in a strong correlation (r=0.84) in a sample of 48 boys and girls age 15.4±0.7 years. Boreham et al. suggested the PWC-170 protocol is a valid predictor of maximal oxygen uptake in adolescents.\textsuperscript{53} In another study by Rowland et al., PWC-170 was compared again to VO₂max. The correlation was slightly weaker in this study than the Boreham study at r=0.71 for girls and r=0.70 for boys. When both variables were expressed relative to body mass in kilograms, the correlation was even weaker (r=0.65 and 0.48 for girls and boys, respectively). The researchers predicted VO₂max for each subject using their individual regression equations of PWC-170 on VO₂max and this introduced further error. The girls and boys had a mean error from the measured VO₂max of 3.4 ml/kg/min (SD 2.5) and 2.8 ml/kg/min (SD 2.6), respectively. This study did not provide strong evidence supporting the use of the PWC-170 in adolescents to accurately estimate individual VO₂max; however, it may be useful for a crude estimate of VO₂max.\textsuperscript{54}
Treadmill Calibration Test for Accelerometers

Generalized equations exist that estimate EE from accelerometer counts; however, these equations have been found to be less accurate for some activities and intensity levels. In order to develop more accurate, individualized equations, each subject completed a graded submaximal treadmill exercise test. While performing the exercise, subject’s oxygen consumption was measured using the ParvoMedics’ metabolic system (ParvoMedics’ TrueOne 2400, ParvoMedics, Sandy, UT).

A treadmill protocol was developed because the goal was to have the activity during the calibration test to be as similar as possible to the actual activity the students were to perform during class. Prior to protocol commencement, subjects were fitted with a heart rate monitor and their assigned accelerometer. The protocol was explained and subject questions were clarified before beginning the test. They were then fitted with the headgear, mouthpiece, and noseclips, and secured to the metabolic system. The protocol (Table 4) involves three-3 minute stages of exercise at speeds of 1.7 mph, 3.0 mph, and 4.2 mph. A fourth minute will be added to a stage if steady state was not reached during the first 3 minutes. During the exercise protocol, one researcher recorded heart rate and VO$_2$ at the end of each minute of exercise and the subject’s rating of perceived exertion was recorded at the end of each stage. At the conclusion of the test, subjects walked slowly on the treadmill until heart rate returned to near-resting level.
Table 4
*Treadmill Calibration Test Protocol*

<table>
<thead>
<tr>
<th>Stage</th>
<th>Speed</th>
<th>Minute</th>
<th>Heart Rate</th>
<th>VO₂</th>
<th>RPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.7 mph</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 (if nec.)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3.0 mph</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 (if nec.)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4.2 mph</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 (if nec.)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cool-Down</td>
<td>1.7 mph</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Add a fourth minute if steady state was not reached by the third minute.

With the results of each test, linear regression was used to generate individualized equations to predict EE from accelerometer counts. Prediction equations were created by assuming a linear relationship between the explanatory variable, x, and the response variable, y. The x-values consisted of the subject’s accelerometer vector magnitude (uses all three axes) at rest (assumed to be zero counts) and the three different stages of the treadmill test. The corresponding y-values were the subject’s VO₂ measurements at those same four time points (with rest assumed to be 3.5 ml/kg/min of O₂⁵⁶). As each stage of exercise provided more than 1 x- and y-value, the average of the last four 30-second periods (steady-state) of exercise was used to determine the accelerometer counts and VO₂ estimates.

Each subject’s regression equation was used to estimate oxygen consumption for a given accelerometer count value. This method was used to determine EE during each class and during
the week-long wear periods. As each equation provided an estimation of oxygen consumption for a 30-second period, these values were then converted to kilocalories by using each subject’s body weight and normal conversion factors.

\[
\frac{VO_2 (ml/kg/0.5 min) \times Body\ Weight\ (kg) \times 0.5\ mins}{1000\ ml} = VO_2 (L) \times 5\ kcs/L O_2 = kcs
\]

To determine kilocalories for each class period, the above equation was used for each 30-second time point, then all 30-second time points were summed to determine the caloric cost of exercise during class.

**Dual-Energy X-Ray Absorptiometry (DXA)**

A DXA (Lunar iDXA, GE Healthcare, Fairfield, CT) was used to assess body composition of the subjects at baseline. During the first class period, subjects were provided information regarding the DXA scan and each signed the DXA risk form. The purpose of the risk form was to inform the students about the risk of exposure to radiation. Subjects were instructed to wear thin clothing and remove all jewelry before arriving for their scan and were reminded again before the scan began. Subjects were provided scrubs if their attire was inappropriate. Females were given the opportunity to take a pregnancy test prior to their scan as it is unknown whether the radiation from the scan may cause fetal harm. All pregnancy tests were negative and all subjects were able to participate in the DXA scan. DXA-trained individuals conducted the scans and analyzed the results.

Total body composition measurements from the DXA have been found to be very precise with coefficients of variation (CV) less than 1% and correlations near one \(R^2=0.98-0.99\). More importantly, the precision error has been estimated as a CV of 0.86% for calculation of body fat percentage from the GE Lunar iDXA and consecutive measurements were reported to
be in strong agreement ($R^2=0.99$). The effect of body size on measurement precision has not yet been examined.\textsuperscript{57}

**Accelerometry**

**Specifications**

Actigraph GT3X and Actigraph GT3X+ accelerometers (Actigraph, Pensacola, FL) were used to determine the amount and intensity of physical activity the subjects performed during the exercise intervention as well as their total EE at baseline, week 5, and week 8 of the intervention. The intention was to use the same model of accelerometer for all measurements. However, measurement demands required the use of different models across subjects. The manufacturer claims that both the GT3X and GT3X+ use the same mechanism and therefore will measure activity uniformly.\textsuperscript{42} With few exceptions, subjects used the same accelerometer for all testing and data collection. Exceptions included monitor failure or errors that required monitor replacement.

The GT3X and GT3X+ are triaxial activity monitors that measure acceleration using a microelectric mechanical sensor (MEMS) in all 3 axes. When fully charged, the battery lasts 21 days and 8 days for the GT3X and GT3X+, respectively, but can change depending on the number of axes enabled and the rate of data collection. The difference in battery life is largely due to the Amp hour of the battery in each model. In conjunction with the associated ActiLife software, this measurement tool provides useful output such as EE, time spent in sedentary, light, moderate, and vigorous activity, and wear time.\textsuperscript{42}
**Wear Time**

In order to measure the amount and intensity of activity the students performed during class, the monitor was worn during class each day (Tuesday and Thursday, 11:00-12:15). To estimate the amount of activity the subjects performed during their usual daily life, the accelerometers were worn during 3 different weeks throughout the intervention: Week 1 (January 10-January 17), Week 5 (February 7-February 14), and Week 8 (February 28-March 6). A study by Trost recommended a wear period of 3 days in adult subjects; however, Napolitano et al., recommend considering 7 days of wear time instead of the minimum of 3 to ensure adequate data were obtained to estimate daily EE. Because of these findings, the subjects in the present study were required to wear accelerometers for 7 day wear periods.

Participants logged accelerometer wear time during the week-long wear periods. Subjects were told to wear the monitor every day for all waking hours except when exposed to water (swimming or bathing). If a student’s wear time was insufficient or the monitor did not work, the individual was asked to wear the accelerometer during a different week (week 2 to account for week 1 and week 7 to account for week 5). Specifically, 4 subjects were asked to re-wear the monitor in week 2, and 4 subjects in week 7. In cases where wear time was insufficient, an additional week of accelerometer wear did not always prove to be effective. If the subjects were not compliant for the first week, they were not necessarily more compliant the second week. However, this method seemed to be effective if the original monitor was faulty and the subject was compliant to begin with.
Initialization and Analyses

Initialization of the monitors was completed using ActiLife 5.0 software (Actigraph, Pensacola, FL). The GT3X accelerometers were initialized to collect data in 30-second epochs and the GT3X+ accelerometers at a rate of 30Hz (but downloaded in 30-second epochs) and both had 3 axes enabled. The accelerometer data were analyzed using MeterPlus (Santech, Inc., San Diego, CA) and ActiLife 5.0 software. After each class period, the data from the accelerometers were uploaded and analyzed using the regression equations developed from each subject’s calibration test. This analysis provided EE (in kilocalories) for each subject during the class periods. These data were also analyzed using ActiLife to determine the amount of time each person spent at different intensity levels (moderate, vigorous, very vigorous) during class. Cut points have been developed by Freedson et al. that can be used to classify activity at varying intensity levels (i.e. light, moderate, vigorous, and very vigorous). In addition, ActiLife uses generalized equations to calculate EE (in kilocalories), though the present study will only use these equations for comparison purposes. The equations that have been developed are as follows:

**Work-Energy Theorem:**
\[ \text{Kcals} = \text{Counts} \times 0.0000191 \times \text{Mass (kg)} \]

**Freedson Equation:**
\[ \text{Kcals} = \frac{\text{Scale} \times (0.00094 \times \text{Counts} + (0.1346 \times \text{Mass (kg)} - 7.37418))}{60} \]

**Combination Work Energy Theorem/Freedson Equation:**
\[ \text{Kcals} = \begin{cases} \text{Work/Energy Theorem for Counts} < 1952; & \text{Freedson Equation for Counts} \geq 1952 \end{cases} \]

To obtain a measurement of average daily EE, the counts for each subject were standardized for valid wear time. Only those subjects with at least 8 hours/day on at least 4 days of the wear period were included in the analysis. Using the total number of counts over the valid hours of wear, a variable of counts/valid minute was created. The counts per each 30-second
time period were then converted to kcals/30-seconds using each subject’s individual regression equation. The value of kcals/30-seconds was converted to a 14-hour period, making the assumption that the counts during the subject’s wear period is an accurate representation of all waking hours of the day. Accordingly, 10 hours were estimated to be resting/sleeping hours and were assumed to be equivalent to 1 kcal/kg/hour.\(^{56}\)

*Validity and Reliability*

No validity testing has been performed on the Actigraph GT3X+ monitor as it was introduced in 2011; however, it uses the same mechanism as the GT3X model and should theoretically be just as reliable and valid. The inter-instrument reliability for the Actigraph GT3X has been found to be \(r=0.99\).\(^{59}\) When compared to ActivPAL and SenseWear Pro, Actigraph was considered more valid at classifying the intensity of activity at different speeds when used on level ground.\(^{60}\) The Actigraph monitors discriminate between speeds of 2-5 mph well, but a plateau effect occurs at speeds between 6-12 mph. At higher speeds, the accelerometer doesn’t discriminate between activity levels as well.\(^{61}\)

*Diet Recall*

Students completed three 24-hr diet recalls at the same three time points of the intervention as the accelerometer: weeks 1, 5, and 8. The purpose of the diet recall was to estimate changes in EI across the study time period. The diet recall program was developed by the National Cancer Institute and is titled the Automated Self-Administered 24-hr recall (ASA24). The program is internet-based and the results are analyzed using the software program rather than a paid nutritionist. Each subject has a login username and password so he or she can access the website to enter food for the day. For each assessment point, subjects were told to
complete a 24-hr diet recall for 2 weekdays and one weekend day. The website is user-friendly as each step of the recall is explained by an animated penguin. This setting can be disabled at anytime, though it is beneficial for new users.

**History and Development**

The ASA24 is based on the U.S. Department of Agriculture Automated Multiple-Pass Method (AMPM) and the Food Intake Recording Software System (FIRSSpt) which was developed by Dr. Tom Baranowski. This method is a 5-step process to interview the individual about their dietary consumption during the previous 24-hour day. The participants are given cues to help them remember and record what they ate. This diet recall was first developed as a pencil-and-paper version, but is now computerized. This type of questionnaire has been used in large-scale studies such as What We Eat America (WWEA) and National Health and Nutrition Examination Survey (NHANES).

**Data Cleaning**

After each diet recall week, one of the researchers logged into the website to request the results. An excel spreadsheet was created that included dietary information about each subject’s diet recall day. For the purposes of the present study, only daily caloric intake was used. Subjects were excluded from the diet analysis if they did not have at least one weekday and one weekend day complete for a given measurement period. For individuals that completed all three days for a given week, the two weekdays were averaged and weighted as 5/7 of the week. The one weekend day was weighted as 2/7 of the week. For individuals with only one weekday and one weekend day, the one weekday was weighted as 5/7 and the one weekend day was weighted as 2/7. This method served the purpose of determining the average EI over each one-week period.
Validity and Reliability

The USDA created the concept that was used to develop the ASA24. The automated multiple-pass method (AMPM) has been involved in several validation studies, two of which were referenced by the National Cancer Institute. Moshfegh et al. conducted a study, which compared the AMPM method to doubly-labeled water. Results indicated that the AMPM method underreported total EE by 10% in males and 12% in females. Normal weight subjects were found to report more accurately with <1% of males and 6% of females underreporting. Other studies found similar results of slight underreporting using the AMPM method or no difference between doubly-labeled water and AMPM. On the contrary, Subar et al. showed 12-14% of males and 16-20% of females underreported on the AMPM compared to doubly-labeled water. The results of all of the mentioned AMPM studies indicate its efficacy compared to the food frequency questionnaire (FFQ) which has been shown to underestimate total EE by 27%. According to a study by Blanton et al., two unannounced AMPM diet recalls were not significantly different from EE as determined by DLW. The AMPM more accurately displayed EI than the Block food-frequency questionnaire and Diet History Questionnaire, and was similar to a 14-day food recall.

Data Analyses

Energy Intake

Subjects were included in this analysis if they had complete diet data at all three time points: weeks 1, 5, and 8. Complete data was considered having at least 1 weekday recall and 1 weekend day recall. To account for a day of the week effect, the weekday (if only 1) was weighted as 5/7 while the weekend day was weighted as 2/7 of the average EI. If two weekdays
were collected, these days were averaged and then weighted as 5/7 of the average EI. One-way repeated measures ANOVA was run on the valid subjects to compare EI across the time points.

**Energy Expenditure**

Intervention activity was quantified using individual regression equations to determine kilocalories expended during class. In addition, ActiLife 5.0 software was used to classify activity into intensity categories.

To determine the minimum accelerometer wear to elicit a reliability of 0.8, an Intra-Class Correlation (ICC) was completed on subjects with 8 hours a day of valid accelerometer data during the first 7-day wear period. If other subjects had 7 days of valid wear time during either week 5 or 8, they were added to the ICC as long as there were no duplicate subjects. It was determined that 4 days of EE data would provide a reliable (ICC = 0.82) estimate of weekly EE. Accordingly, a minimum of 8 hours/day on at least 4 days of the week were required to be included in the analysis. In addition, subjects were only included if they had complete data from all three wear periods. One-way repeated measures ANOVA was performed to assess whether any differences were apparent among the three comparisons: baseline to week 5, week 5 to week 8, and baseline to week 8.

**Individual Variability**

To examine the extent of inter-individual variability in the changes in EE and EI from baseline to week 8, histograms were created using SPSS (IBM Corp., Armonk, NY). The histograms include only those subjects with complete and valid data for the outcome variable (EE or EI) in question.
Differences between Groups

The differences in EE and EI by groups were examined using two-way ANOVA. To be included in these analyses, subjects were required to have complete and valid data for the outcome variable being examined (EE or EI). This test was used to compare the compensatory response by gender and exercise intensity.

Pearson’s correlation was used to assess the association between body composition and compensatory changes. Similar to the two-way ANOVA, subjects were required to have complete and valid data for the outcome measure being analyzed. The following relationships were assessed by correlation: EE and BMI, EE and body fat percentage, EI and BMI, and EI and body fat percentage.

Weight Change

Actual weight change was determined by assessing the weight of the subjects during weeks 1 and 8. Predicted weight change was determined by calculating the total EE of the intervention activity. The calculated EE for each class period attended was summed and converted to a weight (kcals of activity ÷ 7700 kcals/kg = predicted weight loss in kg) for each participant. This allowed a comparison of predicted versus actual weight change for each subject.

Generalized versus Individualized Regression Equations

An analysis was not completed to compare the validity of the individualized regression equations as that was beyond the scope of this study. However, to assess the similarities between estimates from the alternative equations, a simple line graph was created.
CHAPTER 4

RESULTS

Subjects

The subjects for the study included 20 undergraduate students at The University of Georgia (Table 5). The participants were predominantly female and the average age of the subjects was 20.6 ± 1.5 years, and the average height and weight were 170.3 ± 14.6 cm and 68.7 ± 12.9 kg, respectively. According to the American College of Sports Medicine guidelines, the men were of above average fitness level with an average $\text{VO}_{2\text{max}}$ of 48.8 ± 2.6 ml/kg/min as determined by a submaximal fitness test while the women were of average fitness level with an average $\text{VO}_{2\text{max}}$ of 37.7 ± 8.3 ml/kg/min. The average BMI and body fat percentage of all subjects were 24.1 ± 4.6 kg/m$^2$ and 32.4 ± 9.6%, respectively.

Table 5
Subject Characteristics at Baseline

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N$</td>
<td>20</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Age (years)</td>
<td>20.6 ± 1.5</td>
<td>21.3 ± 0.6</td>
<td>20.3 ± 1.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.3 ± 14.6</td>
<td>187.0 ± 8.6</td>
<td>162.0 ± 2.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>68.7 ± 12.9</td>
<td>75.4 ± 4.6</td>
<td>65.1 ± 14.6</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>24.1 ± 4.6</td>
<td>22.9 ± 1.7</td>
<td>24.8 ± 5.5</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>32.4 ± 9.6</td>
<td>23.2 ± 5.1</td>
<td>37.3 ± 7.5</td>
</tr>
<tr>
<td>$\text{VO}_{2\text{max}}$ (ml/kg/min)</td>
<td>41.8 ± 8.7</td>
<td>48.8 ± 2.6</td>
<td>37.7 ± 8.3</td>
</tr>
<tr>
<td>Energy Intake (kcals/day)</td>
<td>1973.4 ± 494.9</td>
<td>2326.7 ± 511.7</td>
<td>1748.5 ± 341.0</td>
</tr>
</tbody>
</table>
Quantification of Exercise

The purpose of the current study was to quantify the compensation that occurs in energy intake (EI) and energy expenditure (EE) in response to the addition of a structured exercise program. The subjects were randomized into either a walking or jogging group, and these groups received different doses of physical activity (Figure 3). The walking group performed mostly moderate activity during the approximately 60 minutes of exercise during class while the jogging group performed a mixture of moderate and vigorous activity with moderate still being the dominant intensity. All participants completed nearly 2 hours of moderate to vigorous intensity exercise each week for 8 weeks (walking average = 116.6 mins/week, jogging average = 110 mins/week). The difference in activity time between the classes may have been due to the jogging class tiring out sooner than the walking class because of the higher-intensity exercise. Students attended an average of 86% of the class periods and everyone attended at least 11 of the 15 classes.

It is clear that the two classes performed varying amounts of activity at the different intensities; however, when energy expended is compared, there is only a very small difference between the classes. On average, the walking class expended 431.2 kcals/class while the jogging class expended 412.2 kcals/class. When expressed relative to body weight, there was still little difference between the two classes (walk = 6.59 kcals/kg/class, jog = 5.99 kcals/kg/class). If anything, the walkers actually expended more energy during class, on average, than the joggers. Although the joggers performed a larger percentage of activity time in vigorous activity, the walkers performed a longer duration of activity on average. This may have contributed to the small difference in EE between the two classes.
Comparison of Generalized and Regression Equations

As stated previously, there are two ways to determine EE via accelerometer data. The present study focused on the individual regression equations that were created by finding the linear relationship between oxygen uptake and accelerometer counts during a graded treadmill test. Figure 13 displays the class period EE estimates obtained from both methods. The methods appear to follow a similar pattern, as expected, but the regression equation generates slightly larger estimates of EE (Figure 4).
Dietary Compensation

Dietary intake has a large influence on the success of a weight loss program. When examining only the subjects with complete EI data \((n = 14)\), no significant difference in average daily EI among the three time periods \((p = 0.23)\) was observed. Overall, the group did not compensate by changing diet in response to the exercise intervention.

The average EI from baseline to week 5 increased by 100.7 kcals/day, while it decreased from week 5 to week 8 by 293 kcals/day (Table 6). Though these differences were not significant, an increase of 100.7 kcals/day over the 25 days of the first half of the intervention would correspond to a body weight increase of 0.32 kg. From week 5 to 8, an average decrease of 293 kcals/day would correspond to a body weight decrease of 0.95 kg. Knowing this, based on diet changes alone, the group would have been expected to lose an average of 0.63 kg over the course of the intervention.

Even though the group as a whole did not compensate in response to the intervention, there was a substantial amount of individual variability among the group. The change in average daily EI from baseline to week 8 ranged from -1199.48 kcals/day to 1503.201 kcals/day. The variability across subjects in changes in EI from baseline to week 8 is shown in Figure 5.

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Comparison of EI across Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Week 1</td>
<td>14</td>
</tr>
<tr>
<td>Week 5</td>
<td>14</td>
</tr>
<tr>
<td>Week 8</td>
<td>14</td>
</tr>
</tbody>
</table>

^aExpressed as group mean ± standard deviation
Activity Compensation

To evaluate whether physical activity compensation was apparent in this group, the change in average daily activity was examined. Only the 11 individuals with complete data for all three weeks were included in the analysis. For this analysis, accelerometer counts were converted to EE per valid hours on valid days. Individual regression equations were then used to estimate average kilocalories expended per day during each week-long wear period. The analysis of this data showed no significant difference in average daily EE between the three wear weeks ($p = 0.52$).

Though the changes in EE across the intervention were not significant, the average for the group increased by 13.0 kcals/day from week 1 to week 5 and an additional 157 kcals/day from week 5 to week 8 (Table 7). If these changes in EE were consistent over the course of the
intervention period, they would correspond to a weight loss of 0.04 kg for the first half, and 0.51 kg for the second half of the intervention, leading to an overall average weight loss of 0.55 kg.

Although no significant compensation was found for the group as a whole, the change in EE from week 1 to week 8 ranged from -181.0 kcals/day to +436.4 kcals/day. The variability across subjects in change in EE from week 1 to 8 is displayed in Figure 6.

Table 7

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>$\bar{x} \pm SD^a$</th>
<th>F</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>11</td>
<td>2129.4 ± 619.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week 5</td>
<td>11</td>
<td>2142.3 ± 554.8</td>
<td>0.68</td>
<td>2</td>
<td>0.52</td>
</tr>
<tr>
<td>Week 8</td>
<td>11</td>
<td>2299.4 ± 571.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^a$Expressed as group mean ± standard deviation

Figure 6. Distribution of Changes in EE from Baseline to Week 8
Compensatory Responses Between Genders

The changes in EE and EI by gender are displayed in Table 8. No difference was observed in the changes in average daily EI between men and women from baseline to week 5 ($p = .86$) or from baseline to week 8 ($p = .60$). The same insignificant result was found for average daily EE between genders from baseline to week 5 ($p = .56$) and from baseline to week 8 ($p = .35$). It appears that men on average increased EE from baseline to weeks 5 and 8 more than the women did. The females actually decreased EE from baseline to week 5. Both genders on average increased EI from baseline to week 5 and decreased EI from baseline to week 8; however, the change in EI on average for the women was of greater magnitude than the men for both time periods. Similar to the previous analyses, only subjects with complete data were included in this analysis.

During class, the males expended more calories on average (490.9 kcals/class) than the females (379.7 kcals/class) (Figure 7). However, when expressed relative to body weight (Figure 8), there was only a small difference in average caloric expenditure between genders (males = 6.6 kcals/kg/class; females = 6.0 kcals/kg/class). Though there was quite a large difference in absolute EE during class, relatively, there was only a small difference in the EE of men and women. Neither of the groups compensated by changing EE or EI, but the small difference in EE during class between genders may have contributed to the insignificant difference in compensation.
Table 8

Changes in EE and EI by Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>n</th>
<th>Baseline to Week 5</th>
<th>Baseline to Week 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in EE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3</td>
<td>94.3 ± 288.1</td>
<td>119.0 ± 209.7</td>
</tr>
<tr>
<td>Females</td>
<td>8</td>
<td>-5.8 ± 230.6</td>
<td>37.9 ± 78.3</td>
</tr>
<tr>
<td>Change in EI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>4</td>
<td>40.6 ± 1130.1</td>
<td>-33.1 ± 1137.8</td>
</tr>
<tr>
<td>Females</td>
<td>10</td>
<td>124.7 ± 576.8</td>
<td>-257.0 ± 440.5</td>
</tr>
</tbody>
</table>

*aExpressed as group mean ± standard deviation

Figure 7. Energy Expenditure across Class Periods, by Gender

Figure 8. Energy Expenditure across Class Periods Controlled for Body Weight, by Gender
Impact of Body Composition on Compensation

Energy Expenditure

A moderately negative relationship \( (r = -0.40) \) between body fat percentage and the change in EE from baseline to week 8 was observed in this study (Figure 9). As body fat percentage increased, the change in activity from week 1 to week 8 decreased. Based on the \( R^2 \) value, 12.6% of the variability in the change in daily EE could be explained by baseline body fat percentage.

Surprisingly, the correlation between BMI and the change in EE was very different from that observed for body fat percentage (Figure 9). Specifically, a weak, negative correlation \( (r = -0.15) \) was observed. However, BMI does not directly measure body composition. Rather, it is a clinical method to assess whether an individual is at a healthy weight for his or her height.

![Figure 9. Correlation of Baseline Body Fat (a) and BMI (b) with Change in Average Daily EE from Baseline to Week 8](image)

Energy Intake

There was a moderately negative correlation between body fat percentage \( (r = -0.36) \) and change in EI (Figure 10). For this relationship, 13.0% of the variability in change in daily EI
could be explained by body fat percentage. Those individuals with the highest percentage of body fat actually decreased their intake from baseline to week 8 while those with a lower percentage of body fat were more likely to maintain or increase their average daily EI.

A weak, negative relationship between BMI and change in EI (Figure 10) was observed ($r = -0.25$). Only 6.3% of the variability in EI could be explained by BMI.

![Figure 10. Correlation of Baseline Body Fat (a) and BMI (b) with Change in Average Daily EI from Baseline to Week 8](image)

**Effect of Exercise Intensity on Compensation**

The walking and jogging classes provided similar amounts of total moderate and vigorous physical activity on average throughout the 15 class periods. The walking class performed an average of 58.3 minutes of moderate and vigorous physical activity while the joggers were active for about 55.0 mins during each class period (Figure 3). The caloric expenditure of the students in the two classes was also similar (Figure 11). Even when expressed relative to body weight, there was little difference in average EE between the walkers and joggers (Figure 12).
No significant difference was found in the change in EE from baseline to week 5 ($p = .58$) or baseline to week 8 ($p = .38$) in the walking or jogging groups. Similarly, the walking and jogging groups were not significantly different in their change in EI from baseline to week 5 ($p = .71$) or baseline to week 8 ($p = .26$).

There seemed to be no pattern in the changes in EE and EI by exercise intensity (Table 9). The walking group decreased average EE from baseline to week 5 and increased average EE from baseline to week 8, while the joggers increased average EE during both time points. The walkers decreased average EI during both time points, while the joggers increased average EI from baseline to week 5, but decreased average EI from baseline to week 8.

![Figure 11. Energy Expenditure by Class Period](image1)

![Figure 12. Energy Expenditure by Class Period Controlled for Body Weight](image2)
Table 9

Changes in EE and EI by Exercise Intensity

<table>
<thead>
<tr>
<th>Class</th>
<th>N</th>
<th>Baseline to Week 5</th>
<th>Baseline to Week 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>7</td>
<td>-14.7 ± 284.1</td>
<td>74.4 ± 143.7</td>
</tr>
<tr>
<td>Jogging</td>
<td>3</td>
<td>87.6 ± 159.2</td>
<td>35.4 ± 93.2</td>
</tr>
<tr>
<td>Walking</td>
<td>6</td>
<td>-55.5 ± 765.3</td>
<td>-412.6 ± 426.2</td>
</tr>
<tr>
<td>Jogging</td>
<td>7</td>
<td>329.4 ± 702.9</td>
<td>-29.3 ± 852.4</td>
</tr>
</tbody>
</table>

*Expressed as group mean ± standard deviation

Relationship between Energy Intake and Energy Expenditure

An analysis was done to examine the relationship between changes in EI and EE from week 1 to 8 (Figure 13), and a weak, negative relationship was found ($r = -.17$). It appears that as individuals decreased average EE, they also increased their EI. This may be an indicator that if an individual compensates in one area, they are more likely to compensate in the other. When the individuals were examined separately, there did not seem to be a pattern across subjects. Some individuals compensated (or did not compensate) in both areas while others compensated in one but not the other.

![Figure 13. Relationship between EE and EI from Baseline to Week 8](image-url)
Weight Change

The exercise intervention was in place to produce an energy deficit in the subjects in order to measure the response to the perturbation to energy balance. The average EE during a typical class period was 422.2 kcals. The energy cost of the exercise over time, if diet remained stable, would produce a weight loss of approximately 0.82 kg on average by the end of the intervention. Figure 14 illustrates an important problem of many weight loss programs: individual variability in weight change in response to exercise interventions. Most subjects’ change in weight differed substantially from the amount of weight loss expected from this intervention. While error in weight measurement may explain minor differences, larger differences are most likely due to changes in EI or non-exercise EE during the course of the intervention.

![Figure 14](image_url)

Figure 14. Expected Weight Change Versus Actual Weight Change.

The actual weight change of the subjects was very weakly correlated to the change in EE (baseline to week 5: \( r = -.27 \); baseline to week 8: \( r = -.10 \)). A modest correlation was found
between actual weight change and change in EI (baseline to week 5: \( r = 0.30 \); baseline to week 8: \( r = .35 \)). Each subject’s weight change and the changes in EE and EI through the intervention are shown in Tables 10 and 11.

Table 10

<table>
<thead>
<tr>
<th>Subject</th>
<th>Weight Change (kg)</th>
<th>EE Change Week 1 to 5 (kcals/day)</th>
<th>EI Change Week 1 to 5 (kcals/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-1.10</td>
<td></td>
<td>1080.38</td>
</tr>
<tr>
<td>3</td>
<td>-0.59</td>
<td>76.93</td>
<td>-563.36</td>
</tr>
<tr>
<td>5</td>
<td>-2.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.38</td>
<td>-507.88</td>
<td>-658.48</td>
</tr>
<tr>
<td>9</td>
<td>0.29</td>
<td></td>
<td>712.16</td>
</tr>
<tr>
<td>11</td>
<td>0.46</td>
<td>-81.36</td>
<td>114.38</td>
</tr>
<tr>
<td>12</td>
<td>-1.28</td>
<td>-87.77</td>
<td>598.50</td>
</tr>
<tr>
<td>13</td>
<td>-2.72</td>
<td>127.83</td>
<td>-484.49</td>
</tr>
<tr>
<td>17</td>
<td>-3.76</td>
<td></td>
<td>-603.03</td>
</tr>
<tr>
<td>19</td>
<td>2.12</td>
<td></td>
<td>73.82</td>
</tr>
<tr>
<td>21</td>
<td>-1.29</td>
<td>-187.02</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>1.42</td>
<td>178.86</td>
<td>334.45</td>
</tr>
<tr>
<td>23</td>
<td>0.86</td>
<td>81.04</td>
<td>-1110.00</td>
</tr>
<tr>
<td>25</td>
<td>-1.98</td>
<td>222.86</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>-1.86</td>
<td>388.78</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>-0.18</td>
<td>-55.60</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>-1.64</td>
<td></td>
<td>-295.32</td>
</tr>
<tr>
<td>33</td>
<td>-3.06</td>
<td>-1.26</td>
<td>39.65</td>
</tr>
<tr>
<td>37</td>
<td>1.18</td>
<td></td>
<td>-19.00</td>
</tr>
<tr>
<td>38</td>
<td>2.14</td>
<td></td>
<td>1586.82</td>
</tr>
</tbody>
</table>

Note: Shading indicates insufficient or incomplete data.
<table>
<thead>
<tr>
<th>Subject</th>
<th>Weight Change (kg)</th>
<th>EE Change Week 1 to 8 (kcals/day)</th>
<th>EI Change Week 1 to 8 (kcals/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-1.10</td>
<td></td>
<td>-328.46</td>
</tr>
<tr>
<td>3</td>
<td>-0.59</td>
<td>32.99</td>
<td>-21.58</td>
</tr>
<tr>
<td>5</td>
<td>-2.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.38</td>
<td>-71.52</td>
<td>-548.44</td>
</tr>
<tr>
<td>9</td>
<td>0.29</td>
<td></td>
<td>355.90</td>
</tr>
<tr>
<td>11</td>
<td>0.46</td>
<td></td>
<td>33.43</td>
</tr>
<tr>
<td>12</td>
<td>-1.28</td>
<td>-56.04</td>
<td>178.36</td>
</tr>
<tr>
<td>13</td>
<td>-2.72</td>
<td>130.20</td>
<td>-1097.93</td>
</tr>
<tr>
<td>17</td>
<td>-3.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>2.12</td>
<td></td>
<td>-741.73</td>
</tr>
<tr>
<td>21</td>
<td>-1.29</td>
<td>-71.03</td>
<td>-892.33</td>
</tr>
<tr>
<td>22</td>
<td>1.42</td>
<td>152.83</td>
<td>-163.17</td>
</tr>
<tr>
<td>23</td>
<td>0.86</td>
<td>83.91</td>
<td>-1199.48</td>
</tr>
<tr>
<td>25</td>
<td>-1.98</td>
<td>32.03</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>-1.86</td>
<td>343.97</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>-0.18</td>
<td>53.93</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>-1.64</td>
<td>147.63</td>
<td>-436.24</td>
</tr>
<tr>
<td>33</td>
<td>-3.06</td>
<td>28.49</td>
<td>-236.13</td>
</tr>
<tr>
<td>37</td>
<td>1.18</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>38</td>
<td>2.14</td>
<td></td>
<td>1503.20</td>
</tr>
</tbody>
</table>

Note: Shading indicates insufficient or incomplete data.
CHAPTER 5
DISCUSSION

The goal of this study was to quantify the diet and activity changes in college-aged participants in a structured exercise program. The main components of compensation, energy intake (EI) and energy expenditure (EE), were examined separately in order to assess the mode by which individuals compensated. The difficulty in analyzing compensation as a group is the lack of ability to explore the individual variability in behavioral changes. The group as a whole did not compensate significantly by either increasing EI or decreasing EE. The small sample size most likely hindered the ability of this study to detect any significant changes in EI or EE.

Previous literature indicates that the behavioral responses to exercise among men and women are substantially different. Men have been found to maintain a stable EI following acute exercise\(^9,\)\(^{35}\) while women tend to increase EI, especially following high-intensity exercise.\(^{36}\) These studies led to the hypothesis that women, but not men, would increase food intake in response to the intervention. The present study found that the changes in average EI and EE among men and women were not different. These results suggest that women do not necessarily compensate more than men.

Previous literature led to the analysis of body composition and its relationship to compensatory behaviors. For instance, Durrant et al. stated that overweight individuals do not compensate by changing diet, as their bodies do not regulate weight as well as normal weight individuals.\(^7\) Normal weight individuals are found to compensate more by increasing EI in
response to an exercise intervention as a physiological mechanism to maintain weight. An animal model comparing non-obese and genetically obese mice showed similar results. Non-obese mice adjusted EI proportionately to the EE of exercise to maintain weight. Obese mice decreased EI with added exercise unlike the non-exercising obese controls. The present study agrees with these prior studies that, with added exercise that offsets energy balance, normal weight individuals appear to be better at maintaining weight by altering EI than obese individuals. In these analyses change in EE and EI were moderately and negatively correlated to baseline body fat percentage. For both situations, the correlations indicate that as body fat percentage increases, smaller increases (or decreases) in EE and EI occurred. The current study suggests that individuals with a higher body fat percentage are more likely to compensate by decreasing non-exercise EE and individuals with a lower body fat percentage are more likely to compensate by increasing EI.

Evidence suggests that body fat percentage is highly correlated with BMI, so it would have been expected that if changes in EE and EI were correlated with body fat percentage, they would also been correlated with BMI. This was not observed in the current study. BMI was weakly correlated to both the change in EE and the change in EI from baseline to week 8. The subjects in the present study may not have been representative of the population as a whole, and therefore this relationship did not hold true. In the population used for the current study, body fat appears to be a better predictor for compensation than BMI, as the coefficient of determination for body fat percentage is higher than BMI for the relationship to change in EE and change in EI.

Church et al. examined weight changes in response to exercise at three different intensities and found that those who had the largest discrepancy between predicted and actual
weight loss were those in the highest intensity group.\textsuperscript{6} Similarly, there were two groups in the present study that exercised at different intensities. Although the walking group performed mostly moderate-intensity activity and the jogging group performed a mixture of moderate and vigorous-intensity activity, the average EE of the two classes differed by only 20 kcals/class. There was no substantial difference in observed compensatory responses between the two groups, but this may be due to study limitations. A greater compensatory response may have been produced had the jogging class yielded an EE greater than that of the walking class for the duration of activity performed. Diet compensation was observed in only the highest intensity group of the Church study, which had a similar EE to participants in the present study. Specifically, the lowest intensity group was prescribed \textasciitilde 330 kcals/week of exercise and the highest intensity group was prescribed \textasciitilde 856 kcals/week.\textsuperscript{6} In the present study, the weekly EE was approximately 844 kcals/week, which, according to previous literature, should have been a large enough dose to produce the expected compensatory behavior changes. Stronger compensatory behavior changes might have been observed if sedentary, unfit subjects were used. The EE and duration of the intervention exercise were comparable to previous studies, so this is most likely not the reason for the minimal compensation in the current study.

The identification of a relationship between EI and EE may be helpful in determining by which mechanism individuals most likely compensate. Only a weak relationship was found between change in EI and change in EE ($r = -.17$), but this concept may be very important to improving weight loss programs. For example, if individuals who compensate do so by both decreasing non-exercise activity and increasing caloric intake, weight loss programs will be even less successful than if compensatory behaviors were likely to only modify one component of
compensation. More specifically, the present study found that decreased non-exercise activity was associated with increased food intake, which can be detrimental to weight loss efforts. However, the reverse of increased non-exercise activity being associated with decreased food intake would strengthen weight loss efforts. In order for exercise-based weight loss programs to be successful, they should be tailored to the individual’s predisposition to compensatory behavior changes. It is clear that not everyone responds the same to added exercise, so different approaches may need to be taken based on the individual and his or her type of behavioral response. Individuals may further benefit from weight loss programs if more attention is given to the prevention of compensation. Compensatory responses and failure to achieve predicted levels of weight loss are thought to be largely due to the behavioral changes in eating and activity patterns, although metabolic adaptations may also play a role.\(^5\)

The main finding of this study was the distinct inter-individual variability in weight changes during the intervention. Although this study did not act to stimulate weight change in subjects, most subjects experienced a shift in weight. If anything, a small decrease in body weight would have been expected in all subjects, assuming diet remained relatively stable, as the intervention itself caused a deficit of approximately 844 kcals/week. Manthou and King also observed individual variability in weight loss from structured exercise, resulting in the researchers’ choice to split their subjects into two groups: non-responders and responders or compensators and non-compensators.\(^{32, 33}\)
Strengths

1. Free-living physical activity was objectively measured using accelerometers. The objective measurement of habitual activity would have been difficult and burdensome without the use of accelerometry.

2. Similarly, EI was measured using multiple 24-hr diet recalls that imparted minimal subject and researcher burden. This method was of no cost, which made it one of the few cost-free methods of EI measurement that was feasible for the current study. In addition, the accessibility, convenience, and ease of use of the program may have helped with compliance compared to more burdensome dietary measures.

3. The physical education course was already in place, which allowed for convenient subject recruitment and participation. The requirement of the physical education course and the earned credit most likely helped with subject participation, compliance, and retention.

Limitations

There were a number of limitations to this study that should be considered when interpreting its findings.

1. The current study had a sample size of only 20 subjects, which greatly reduced the statistical power of the study to detect clinically meaningful differences. This was a large limitation that could be eliminated with a larger sample size. In order to recruit more individuals, incentives such as money, gift cards, coupons, and even t-shirts should be considered in the future if funds are available. The current study did not provide an incentive above what the students would have obtained from any other physical education course at the University of Georgia other than the DXA scan results. In addition, steps could be taken in the
future to contact a larger portion of the students at the University of Georgia (i.e. e-mailing listservs).

2. The exercise intensity of the intervention was mostly moderate for the walking class and a combination of moderate and vigorous for the jogging group; however, the caloric expenditure was similar between the groups. Since both groups performed activity for a similar duration with no large differences in EE, the intensities could not have been substantially different. In order to assess the difference in behavioral responses to different intensities of exercise, there should be a larger difference in the exercise intensity between the groups. In addition, King et al. provided their overweight, sedentary subjects with 500 kcals/day of exercise EE, 5 days a week and reported a significant increase in EI for those individuals who lost less weight than expected. The intervention by King et al. was also a 12-week long intervention compared to the current 8-week intervention. A longer exposure to a stronger exercise stimulus may have led to a greater compensatory response.

3. Accelerometers were used to objectively measure activity participation during class as well as free-living EE during week-long time periods. If funds are available, doubly-labeled water would be the best choice for measuring free-living EE during a longer time frame. However, use of doubly-labeled water would increase subject burden. Other options such as heart rate monitors would also objectively measure activity, but it would be difficult to quantify group activity intensity, as heart rate is specific to the individual. Accelerometers provided complete information about the intensities of exercise and the EE during class. They may be useful for bouts of structured exercise, but more research needs to be done to ensure they accurately measure daily, free-living activity. Combining multiple measures of physical activity
may prove to be useful in the future, especially to ensure the accelerometers accurately measured daily, free-living activity as well as activity during class. In addition, these devices, like any other electronic device, sometimes have technical errors. Asking subjects to wear more than one device might have saved some data, but it would have also added subject burden.

4. Accelerometers capture both sedentary time and free-living activity, although not all aspects of free-living activity are detected due to the location of the monitor. The most common and valid placement for the monitor is the right hip, but this is known to misclassify certain activities such as those that involve limited trunk movement.\textsuperscript{47}

5. Another limitation of accelerometer use is the inaccuracy of the estimation of EE.\textsuperscript{47} The Freedson generalized equation has been shown to underestimate the energy cost of moderate intensity lifestyle activities by as much as 50%. In some cases, the equations have misclassified moderate activity as light activity.\textsuperscript{61} The generalized equations were not used for the present study due to the use of individualized regression equations that were thought to be more accurate for each subject.

6. To be included in the accelerometer data analysis, subjects were required to have at least 8 hours/day, 4 days/week of wear time. This minimum amount of wear time was assumed to be representative of the subjects’ usual 7-day activity, which may not be the case.

7. Regression equations were created for each individual subject in order to better estimate EE from the accelerometer output. These equations related oxygen consumption during a graded exercise test to the corresponding accelerometer counts. In doing so, oxygen consumption from a given activity could be estimated by inserting accelerometer counts into the equation. This method imparted more burden on the researchers than would the already-developed generalized
prediction equations. Further validation testing should be done to assess the improved precision of these individualized equations in comparison to readily available estimates based on generalized prediction equations.

8. The ASA24 24-hour diet recall was used to determine EI at three different time points during the intervention. The online program, in theory, was appropriate for the purpose of the current study; the program was of no cost and did not require the expertise of nutritionists or dieticians to analyze the resulting data. One negative aspect to using an online program is that the subjects may not have felt obligated to complete the recall, resulting in a greater proportion of incomplete diet data from the subjects. Future studies may benefit from using a diet record or recall method that is interviewer-administered by a registered dietician. In addition, the diet recall was completed on only nine days to represent EI changes during an 8-week exercise program. Diet recalls should be done more frequently to acquire a more accurate representation of the diet changes that occur throughout the intervention. Though this method has been widely-used and proven to be accurate at measuring the mean of a group, it may not provide accurate estimates at the individual level. Previous literature indicates underreporting by 10-20%, which may have influenced the estimations of EI for the current study. Fortunately, the present study focused mainly on change in EI rather than the quantification of EI, which is less affected by the underreporting.

9. A college-aged population was chosen for this study because the physical education course already in place at the University of Georgia provided a feasible framework for the exercise intervention. Compared to non-students, college students have highly variable schedules. A daily routine is not always followed, classes are at different times each day of the
week, and evening activities are constantly changing. An individual out of school more likely
works an 8-hour day and follows a more structured daily routine. In the future, subjects should
include adults of all ages and occupations as college-aged individuals are not representative of
everyone who may compensate. The subjects in the current study may also have been more
active at baseline than individuals in prior studies, which may have resulted in different
compensatory responses.

Future Directions

Based on the described strengths and limitations of the current study, the following
recommendations may improve research on this topic.

1. Use of multiple physical activity measurement tools may help improve assessments of the
intervention activity as well as free-living activity EE.

2. Validation testing should be done on the use of individualized regression equations to
estimate EE.

3. If funding is available, a more comprehensive, interviewer-based diet assessment should
be used. Use of dieticians or nutritionists to collect and analyze this information would be costly,
but likely more accurate.

4. A larger sample should be used with incentives provided to motivate individuals to
participate and comply with study protocols.

5. A larger dose of activity is suggested on at least 3 days of the week. At the very least, the
minimum physical activity recommendation of 150 minutes of moderate activity a week should
be met by the intervention.
6. The sample in future studies should include individuals of varying ages, occupations, weights, and activity statuses. This would allow conclusions to be generalized to a larger portion of the population.

**Conclusion**

The present study suggests that compensation did not occur in college-aged males and females. Additionally, no differences were found in compensatory responses between genders or exercise intensities. However, there was strong inter-individual variability across subjects, which may be indicative of individuals responding differently to the same exercise intervention. This can be meaningful for individuals participating in exercise interventions as slight increases in EI or decreases in EE can lead to attenuation of the effects of exercise. If predisposition to compensatory responses in individuals can be identified, it may enable the development of tailored strategies to improve the success of weight loss exercise programs among these individuals.
REFERENCES


APPENDIX A

INFORMED CONSENT

UNIVERSITY OF GEORGIA

INFORMED CONSENT FORM

Psychological predictors of compensatory responses to a structured exercise program

I, _________________________________, agree to participate in a research study entitled
“Psychological predictors of compensatory responses to a structured exercise program” which is
being conducted by Michael Schmidt, Ph.D. at the University of Georgia.

My participation is voluntary. I can refuse to participate or withdraw my consent at anytime
without penalty or loss of benefits to which I am otherwise entitled and will in no way influence
my relation to the University of Georgia. I can have the results of my participation that can be
identified as mine removed from the research records or destroyed. If I decide not to participate
at a later date, or withdraw my consent at any time, I will not be required to withdraw from
PEDB 1990 and my course grade in PEDB 1990 will not be affected. In addition, my PEDB 1990
course grade will not be affected by my participation, or lack thereof, in the research-
specific activities of this project.

The purpose of the study is to:
Learn more about how participation in a structured exercise program can change dietary intake
and non-exercise physical activity levels and to identify psychological traits that may be
associated with these changes.

The procedures are as follows:
In this study I enroll in a special section of PEDB 1990 for which I will receive 1 credit hour.
Once enrolled, I will be randomly assigned to either a walking exercise program (similar to
PEDB 1950) or to a jogging exercise program (similar to PEDB 1930). During the first week of
the study I will complete tests of body composition (height, weight, and dual-energy X-ray
absorptiometry) and aerobic fitness (10-15 minute treadmill test) and will complete a battery of
psychological pen-and-paper tests. In addition, at the beginning, middle, and end of the study I
will be completing a 3-day recall of my food intake and wear a small waist-mounted activity
monitor for 3 consecutive days. My weight will be re-measured at the end of the study.
Regardless of whether or not I participate in the research project, I will be expected to attend the 75 minute class sessions as scheduled and my course grade may be affected by the number of classes I miss (as is the policy for most basic physical education courses). If I am assigned to the walking exercise program I can expect to spend 60 minutes in walking activity. If I am assigned to the jogging exercise program I can expect to spend 30 minutes in jogging activity with an additional 30 minutes spent in walking activity. However, if I am unable to meet these activity goals I will be allowed to take rests as needed and to gradually increase my activity participation over time.

The benefits that I may expect from it are:
The potential benefits of my participation include a free structured physical activity program that will provide health benefits for disease risk and general well-being. In addition, health information regarding my risk of obesity from the DXA scan and my dietary intake information will be provided to me. Humankind may benefit because the data collected will be used to help better understand how participation in exercise can influence other behaviors important for weight management. This may help in the development of more effective interventions to prevent the development of overweight or obesity.

The risks and discomforts include:
I understand that there are some risks associated with this study. These may include:

- The occurrence of exercise-related events including the development of ventricular arrhythmia, myocardial infarction, cardiac arrest, and death as well as the less serious problems of injury to tendons, ligaments, joints and muscles. However, these risks are no greater than those from participation in similar basic physical education classes offered at UGA. Further, the risk of serious events is extremely small in healthy younger adults and the amount of activity I will participate in will be similar to current physical activity recommendations for improved overall health.

- Elevated radiation exposure during my body composition scan by dual energy x-ray absorptiometry. While this dose is very low it does present some risk. This is particularly true if I am pregnant, as the x-rays could harm my unborn child. For this reason I should not participate in this study if I am currently pregnant or plan to become pregnant during this study. (Please review and sign the separate Acknowledgement of Risk from DXA Exam form.)

Research-Related Injury:
The researchers will exercise all reasonable care to protect me from harm as a result of my participation. In the event of an injury as an immediate and direct result of my participation, the researcher’s sole responsibility is to arrange for my transportation to an appropriate facility if additional care is needed. The researchers are not able to offer any financial compensation or payment for medical care. As a participant, I do not give up or waive any of my legal rights.

Confidentiality:
The results of this study will not be released in any individually identifiable form without my prior consent unless otherwise required by law. In other words, I will not be personally identified
if the results of this study are published and my participation will be kept confidential. The data will be coded with my identification number and the list linking the code to my identity will be kept separately in the researcher’s locked office. This list will be destroyed after my participation in the study has been completed.

I have read this document and it has been explained to me. I have had an opportunity to ask questions and they have been answered to my satisfaction.

The primary investigator will answer any further questions about the research, now or during the course of the project, and can be reached by email or telephone at:

The University of Georgia, Department of Kinesiology:
  Michael Schmidt, PhD., schmidtm@uga.edu, 706-542-6577

If there is an emergency related to this study I should first contact my personal physician or go to the emergency room. I understand that I should also notify the study investigator (above) as soon as possible.

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

_______________________ _____________________________ ____________
Name of Participant      Signature                      Date

_______________________ _____________________________ ____________
Name of Researcher      Signature                      Date

Telephone: ______________ Email: ____________________________

Please sign both copies, keep one and return one to the researcher.
Additional questions or problems regarding your rights as a research participant should be addressed to the Chairperson, Institutional Review Board, University of Georgia, 629 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-mail Address IRB@uga.edu.
APPENDIX B

FLYER

NEED A PE CREDIT?

Exercise programs don't always work the way we want them to.

WE WANT TO KNOW WHY, AND YOU CAN HELP!

Register for PEDB 1990 for the Spring 2012 semester. We are accepting people of all shapes and sizes to be part of our research study.

You may qualify if you:
• Are 18-30 years old
• Are willing to be randomized to a walking or jogging class

You do NOT qualify if you:
• Have a health condition or take medication that affects exercise or diet
• Are pregnant, attempting to become pregnant, or lactating
• Have orthopedic issues that don’t allow you to exercise

For more information, contact the researchers at unga.pe.study@gmail.com
E-mail Message Sent to Registered Students

Dear Student,

Thank you for your interest in PEDB 1990! This course has been created for the purpose of a research project. Be aware that there are additional components of this course that are not present in other PEDB courses at Georgia. The standard assignments are the same (attendance, online textbook), and you will still receive 1 credit hour for PE by taking this course. You will also receive a DXA scan (body composition measurement) and a submaximal fitness test. These measurements give valuable information about your body composition and fitness level.

Please carefully read the attached documents, and feel free to e-mail back with questions or concerns regarding this course.

We look forward to meeting you!

Sincerely,

Research Coordinators
Amanda Gipson
Rachelle Acitelli
uga.pe.study@gmail.com
PEDB 1990 Course Syllabus

UNIVERSITY OF GEORGIA
College of Education
Department of Kinesiology

Spring 2012
Behavioral Responses to Exercise
PEDB 1990 – 80-815
TR 11:00 – 12:15 – First 10 weeks of semester
Ramsey Center 117

Instructors: Ms. Amanda Gipson & Ms. Rachelle Acitelli
Office: Ramsey Center/109 I
Phone: (219) 712-0816 OR (704) 488-7586 (Emergencies Only)
Email: uga.pe.study@gmail.com

Office Hours: Monday and Wednesday, 10:00-11:00am
Other office hours are available by appointment

Department Webpage: http://www.coe.uga.edu/kinesiology/
eLearning Commons: http://elc.uga.edu/
(available at the bookstore)
OR online through McGraw-Hill:

Course Description:

This course has been created for the purpose of a research project. There are additional assignments in this course that are not present in other PE courses. However, these measurements provide valuable information regarding your health and wellness. For example, you will receive a DXA scan (body composition measurement) and a submaximal fitness test. The standard assignments are the same as other PEDB courses (attendance, online textbook, fitness log, participation), and will fulfill the University’s PE requirement. The additional research-specific assignments will require 2-3 hours of your time outside of class. These include:

Questionnaires (completed during class)

- Visual Analogue Scale
- Eating Q
- Self-Motivation
- NEO
- UPPS-P
- Reward Responsiveness
- Monetary Choice Questionnaire

Activities (completed outside of class)

- Wear Accelerometer (9-days total)
- Diet Recall (9-days total)
- DXA (30 minutes in lab)
- Fitness Test (40 minutes in lab)
Students will be randomly assigned to either FFL Walking or FFL Jogging. The activity portion of this class will be equivalent to PEDB 1950 or PEDB 1930.

In *FFL Walking*, students will be taught walking techniques to incorporate higher levels of physical activity, and to track their physical activity in their daily lives with the goal of promoting fitness throughout the lifetime. Physical activity is a large part of this course, and students will be expected to participate in moderate to vigorous activity when they are in class.

The *FFL Jogging* class focuses on individual improvement in cardiovascular fitness by regular and progressive jogs. Distance and times for jogs are gradually increased as the semester progresses. Flexibility and muscular strength and endurance exercises are also incorporated into the class’ activity.

Course Objectives:
- After successfully completing this course, students will be able to:
  1. Examine one’s personal attitude toward exercise.
  2. Understand the role of physical activity in human health.
  3. Develop a value for exercise as an integral part of life.
  4. Understand the principles for development and maintenance of aerobic fitness, muscular strength, muscular endurance, flexibility, and for controlling and maintaining a healthy body weight.
  5. Design a personal exercise program to promote better health, physical fitness, and increased quality of life.

Class Policies:
1. Students will abide by the standards as stated by the University Honor Code (see below) and Academic Honesty Policy. These standards can be found in *A Culture of Honesty*, the University’s policy and procedures for handling cases of suspected dishonesty. Detailed information can be viewed at [http://www.uga.edu/honesty](http://www.uga.edu/honesty) to help you understand how the term “academic dishonesty” is defined on this campus.

   *As a University of Georgia student, you have agreed to abide by the University’s academic honesty policy, “A Culture of Honesty,” and the Student Honor Code. All academic work must meet the standards described in “A Culture of Honesty” found at: www.uga.edu/honesty. Lack of knowledge of the academic honesty policy is not a reasonable explanation for a violation. Questions related to course assignments and the academic honesty policy should be directed to the instructor.*

2. Students requesting classroom accommodation must first register with the Disability Resource Center (DRC). The DRC will provide documentation to the student, who must then provide this documentation to the instructor when requesting an accommodation. Students with documented disabilities that affect their ability to participate fully in the course or who require special accommodations are encouraged to speak with the instructor, so that appropriate accommodations can be arranged.

3. Attendance and timeliness is required. (See attendance policy below)

4. Students are responsible for the information provided in class along with the readings from the online textbook and/or supplemental resources. If you are absent when materials are distributed, it is your responsibility to obtain the information from another student.

5. Students desiring to withdraw from this class must do so by the deadline (March 22).

6. Students should read the “Clearance for Safe Exercise Participation” form provided by the instructor. Students with medical conditions should discuss them with the instructor. The instructor will determine whether medical conditions require a waiver or physician clearance.
7. Poor sportsmanship and the use of inappropriate language will not be tolerated. If this occurs, the student will be asked to leave, will be counted as absent, and will need to meet with the instructor. If the student refuses to leave, it is at the instructor’s discretion to reduce the student’s grade.

8. Class begins at 11:00am. If you arrive late to class, you must check in with the instructor.

9. Appropriate attire must be worn – comfortable exercise wear and tennis shoes.

10. The course syllabus is a general plan for the course; deviations announced to the class by the instructor may be necessary.

Course Requirements:

1. This course will consist of discussions, demonstrations, in-class assessments, and written assessments. All updates or changes to the schedule will be announced in class. It is your responsibility to keep up with changes to the syllabus and calendar.

2. Readings, assessments and assignments will be assigned throughout the semester and due dates will be posted by the instructor on eLC. It is your responsibility to keep up with the due dates.

3. Students are required to purchase a textbook for the online fitness component of the course. A total of seven assignments will be due throughout the semester. Students who have already met the PE graduation requirement should turn in a Degree Audit Report (DAR) with the PEDB course listed to the instructor as proof that they have already meet the graduation requirement. These students will be given 40 pts credit for the online fitness knowledge portion of their grade.

4. Students are required to use eLearning Commons (eLC) for this course. Syllabus, class information, the course schedule, exercise tips, the clearance for safe exercise participation, and a link to the online fitness content will be available through eLearning Commons. To access eLearning Commons you will need your MyID, as well as a current password.

Attendance Policy:
Regular attendance and class participation are required and are vital factors into your final grade. The first two absences (including excused and unexcused) will be without penalty. The third absence will have a 10 points grade penalty and the fourth absence will have a 20 point grade penalty. More than four absences will result in a grade of Unsatisfactory. Arriving on-time to class is also part of your attendance grade. Students will lose 1 point of their participation grade for every time they are 5 or more minutes late to class. However, arriving more than 15 minutes late to class will result in an absence. Unless the class time has ended, if a student leaves before/without being dismissed, s/he will be marked absent that day.

The following is a list of occurrences that will deem the student as absent:
1. Inappropriate attire
2. Poor sportsmanship
3. Arriving to class late (after 15 minutes of the start of class)

Grading:
This course is graded as an “S” (Satisfactory) or “U” (Unsatisfactory). In order to determine what grade a student will be awarded, a percentage system will be used. There are 100 possible points to be earned and 70 points are required to earn an “S” in this course.

<table>
<thead>
<tr>
<th>Attendance</th>
<th>40 pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online Fitness Component</td>
<td>40 pts</td>
</tr>
<tr>
<td>• Assessments (6 total)</td>
<td>5 pts each (only earned if 80% score)</td>
</tr>
<tr>
<td>• Jogging-specific assessment</td>
<td>10 pts</td>
</tr>
<tr>
<td>Fitness Log</td>
<td>10 pts</td>
</tr>
<tr>
<td>Participation</td>
<td>10 pts</td>
</tr>
<tr>
<td><strong>Total 100 pts</strong></td>
<td></td>
</tr>
</tbody>
</table>
**Special Note**

We thank you for being a part of our thesis project. It is very helpful to us to have so many willing participants! We are hoping that the results from this study will help open the doors to future research in the area of exercise physiology. Thank you again and way to go for being a part of UGA research!

Tentative Course Outline:

**Assessments will be due Sundays at Midnight**

<table>
<thead>
<tr>
<th>Week</th>
<th>Activity</th>
<th>Online Fitness Content and Due Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Syllabus, procedures, rules Questionnaires Baseline Testing</td>
<td>Read syllabus posted on eLC Complete assessment on eLC Upload profile picture on eLC</td>
</tr>
<tr>
<td>2</td>
<td>Distribute accelerometers Begin Exercise</td>
<td>All students should have purchased access code, registered, logged-in and accessed the site at least once: <a href="http://mhlearningsolutions.com/georgia_PE/login.php">http://mhlearningsolutions.com/georgia_PE/login.php</a></td>
</tr>
<tr>
<td>3</td>
<td>Read section: “Exercise Vocabulary” Complete Assessment Exercise Vocabulary</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Read section: “Health Benefits” Complete Assessment Health Benefits</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>VAS Accelerometer Diet Recall</td>
<td>Read section: “The FITT Principle” Complete Assessment The FITT Principle</td>
</tr>
<tr>
<td>6</td>
<td>Read section: “Behavior Change” until ‘Move it together’</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Read remainder of section: “Behavior Change” Complete Assessment Behavior Change</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Read section: “Preparing and Recovering from Exercise” Complete Assessment Preparing and Recovering from Exercise</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>VAS Accelerometer Diet Recall</td>
<td>Read section: “Nutrition” Complete Assessment Nutrition</td>
</tr>
<tr>
<td>10</td>
<td>Read Jogging-Specific section Complete Course-Specific Assessment Complete online instructor evaluation at <a href="https://ssl.coe.uga.edu/apps/authorize/login.cfm">https://ssl.coe.uga.edu/apps/authorize/login.cfm</a></td>
<td></td>
</tr>
</tbody>
</table>

Important Dates:
- Monday, January 9 – classes start
- Thursday, January 12 – last day to drop courses (until 5pm)
- Friday, January 13 – last day to add courses (until 5pm)
- Monday, January 16 – MLK Day – no classes
- Monday, March 12 – Friday, March 16 – Spring break – no classes
- Thursday, March 22 – withdrawal deadline for Spring semester
- Monday, April 30 – last day of classes for Spring semester
Clearance for Participation in PEDB 1990

In PEDB 1990 students will learn techniques that incorporate higher levels of physical activity and promote fitness throughout the lifetime. Physical activity is a large part of this course, and students will be expected to participate in moderate to vigorous activity during class. Additionally, students in this course must fully understand that they are participants in a research study investigating the effects of structured exercise on college-aged students. As research participants, students are expected to participate in relevant research measures (surveys, questionnaires, physiological and body composition assessments) throughout the semester.

Please answer the questions below to determine your suitability for participation in this course:

1. Are you under the age of 18?  
   Yes  No

2. Are you over the age of 30?  
   Yes  No

3. Are you pregnant or planning to become pregnant in the next 3 months?  
   Yes  No

4. Are you lactating?  
   Yes  No

5. Do you have orthopedic limitations that may prohibit your full activity participation?  
   Yes  No

6. Do you have any physical or mental disorders that preclude participation in moderate intensity activity?  
   Yes  No

7. Do you have any physical or mental disorders that potentially alter dietary intake?  
   Yes  No

If you have answered ‘Yes’ to any of the above questions, participation in this course is not recommended. At this time, we ask that you drop this course and find a suitable replacement course on OASIS.
APPENDIX D

PEDB 1990 ENROLLMENT REPORT

N=63 Eligible Participants

N=53: Received e-mail screening from research team

N=38: Dropped PEDB 1990 course

N=1 Signed Informed Consent

38 Dropped Course due to:
- Academic schedule change
- Not willing to participate in research component

N=15: Remained registered for PEDB 1990 course

N=15: Signed Informed Consent

N=10: Registered for 1990 late and did not receive e-mail screening from research team

N=4: Dropped PEDB 1990 course

N=2 Signed Informed Consent

N=6: Remained registered for PEDB 1990 course

N=6 Signed Informed Consent

4 Dropped Course due to:
- Academic schedule change