THE COMPARISON OF RESTING METABOLIC RATE TO DAILY PHYSICAL ACTIVITY IN ADULTS AGED 55-69 YEARS OLD

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ABSTRACT

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The primary purpose of this study was to determine if the level of physical activity was related to resting metabolic rate (RMR) in an older population. If a relationship existed, physical activity and RMR could be parameters to observe in older populations by health care professionals (physicians, exercise physiologists, etc.) to aid in weight loss, risk factors of diseases, etc. Since RMR comprises 60-80% of an individual’s total metabolism, it is important to determine ways to increase or maintain RMR as an individual ages. Thirty healthy subjects aged 55-69 years old (average age = 60 years) were recruited for this study. RMR was measured two consecutive times using the BodyGem. Anthropometric parameters that were measured included body height and weight, body composition, waist and hip measurements, and abdominal diameter. After RMR and body composition measures were obtained and recorded, subjects were given an accelerometer to wear for two weeks. The accelerometer measured daily steps taken, intensity of physical activity (moderate to vigorous activity), and calories burned through physical activity. A correlation coefficient was used to compare physical activity and anthropometric variables to RMR. A multiple regression was also used to determine which variables were most predictive of RMR. RMR was significantly correlated with every variable except percent body fat, physical activity calories, and physical activity minutes. Daily steps were significantly negatively correlated with RMR, BMI, percent body fat, hip circumference, and abdominal diameter. Physical activity calories were significantly correlated with physical activity minutes while physical activity minutes were significantly correlated with age and percent body fat. The regression analysis provided the following variables to be used in a prediction equation for RMR: age, percent body fat, physical activity minutes, and physical
activity calories. In conclusion, although RMR was not found to be significantly correlated with physical activity level and negatively correlated with the anthropometric measures, the relationships such as daily steps with BMI, percent body fat, hip circumference, and abdominal diameter were able to provide additional information that recording daily steps may aid in weight maintenance and decrease risk factors for various diseases (i.e., cardiovascular disease, diabetes, etc.).
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CHAPTER I
INTRODUCTION

Resting metabolic rate (RMR) is the largest portion of metabolism that represents the amount of calories an individual utilizes at rest daily. RMR is an important measure to monitor because it consists of 60-80% of an individual’s total metabolism (Compher, Hise, Sternberg & Kinosian, 2005; Luhrmann, Herbert, Krems & Neuhauser-Berthold, 2001; Campbell, Crim, Young & Evans, 1994; Visser, Deurenberg, van Staveren & Hautvast, 1995; Sergi, Coin, Bussolotto, Beninca, Tomasi, Pisent, Peruzza, Inelmen & Enzi, 2002; Santa-Clar, Szmanski, Ordille & Fernhall, 2006; Sullo, Cardinale, Brizzi, Fabbri & Maffulli, 2004). Other portions of metabolism include the thermic effect of feeding and physical activity, which consist of 10% and 10-30% of an individual’s total metabolism, respectively (Campbell et al., 1994; Visser et al., 1995). If an individual’s RMR, thermic effect of feeding, and physical activity expenditure is lower than their daily caloric intake, weight gain will occur. Prolonged weight gain can lead to an individual becoming overweight or obese, which may lead to the development of other chronic diseases (e.g., heart disease, cancer, hypertension, diabetes, and metabolic syndrome).

There are milestones in which RMR is increased or decreased (e.g., infancy, childhood, adulthood, elderly). Many theorize that RMR decreases with age. One theory suggests that energy expenditure is decreased with age due to a decline in physical activity (Visser et al., 1995; Rothenberg, Bosaeus, Westerterp & Steen, 2000; Sullo et al., 2004). With a decreased energy expenditure (from lack of physical activity), RMR could also decrease (Visser et al., 1995; Rothenberg et al., 2000; Sullo et al., 2004). One result of decreased physical activity paired with a maintained or increased energy intake is potential weight gain (Sullo et al., 2004; Van Pelt, Dinneno, Seals & Jones, 2001; Aubertin-Leheudre, Goulet & Dionne, 2008; Hurley & Roth,
Another reason RMR decreases with age is based on a decrease in metabolically active fat-free mass (FFM), particularly muscle, due in part to a decrease in physical activity (Gilliat-Wimberly, Manore, Woolf, Swan & Carroll, 2001; Sullo et al., 2004; Hurley & Roth, 2000; Aubertin-Leheudre et al., 2008; Bosy-Westphal et al., 2003; Voorrips et al., 1993; Visser et al., 1995; Campbell et al., 1994). These authors have acknowledged that physical activity is a factor in RMR, but may not be the only one (i.e., metabolically active FFM). Furthermore, Gilliat-Wimberly et al. (2001) suggested that aging is associated with a 1-2% decrease in RMR per decade based on the loss of FFM and gain in fat mass (FM). FFM can be affected by energy restriction (decrease in daily caloric intake) that may occur in aging individuals. Gender is also a factor because women typically have lower FFM than men (Gilliat-Wimberly et al., 2001). The decrease in FFM from these various factors may lead to a decrease in RMR. For example, Wilson and Morley (2003) suggest that a decrease in RMR between 13-20% occurs between the ages of 30 and 80 years. Additionally, since FFM accounts for more than half of the variability in measuring RMR, the decrease in FFM may not only be attributed to decreased energy expenditure, but also to sarcopenia (decrease in muscle mass associated with aging) (Wilson & Morley, 2003).

Additional theories on the decrease of RMR with aging include hormonal changes and a change in energy expenditure due to an altered mechanical efficiency or increased body weight (Visser et al., 1995; Voorrips et al., 1993). Voorrips et al. (1993) also explained that orthopedic problems may impair an individual which could decrease energy expended through physical
activity and lead to further weight gain. Additionally, an increased body weight could decrease mobility, ultimately causing a decrease in physical activity. Mechanical efficiency issues may cause an individual to be limited in the type or amount of physical activity they can safely participate in which could cause a decrease in RMR (Visser et al., 1995; Voorrips et al., 1993). It is clear that an underlying contributor in decreased RMR in older populations is decreased physical activity. Whether it is simply a lack of physical activity (decreased energy expenditure), or a lower level of physical activity causing the loss of FFM and gain of FM, physical activity seems to play a major role in the maintenance of RMR.

Weight gain is a major concern when an individual has a RMR that is decreasing. Continuous weight gain, without intervention or lifestyle changes, will lead to overweight or obesity. Obesity is one of the most prevalent chronic diseases affecting Americans, and may be caused by low energy expenditure; especially particularly low levels of physical activity and reduced RMR. Currently, obesity is thought to affect one in every three Americans (Santa-Clara et al., 2006). Obesity is linked to other chronic diseases including heart disease, cancer, hypertension, diabetes, and metabolic syndrome (Thompson, Gylfadottir, Moynihan, Jensen & Butterfield, 1997; Aubertin-Leheudre et al., 2008; St-Onge, Mignault, Allison & Rabasa-Lhoret, 2007; Stiegler & Cunliffe, 2006). Furthermore, Hurley and Roth (2000) specified that abdominal obesity may be associated with hypertension as well as insulin resistance, glucose intolerance, and abnormal lipoprotein-lipid profiles. While various solutions for weight control and maintenance have been made available, such as published texts, professional interventions, and nation-wide programs like Weight Watchers, controlling this disease has been extremely difficult for many Americans. One suggestion for resolving this epidemic may be to monitor RMR for
patients or clients while they attempt to make appropriate lifestyle changes (e.g., increasing physical activity).

Studying aging adults is especially important because of the increasing evidence of a decreased RMR in this population. While lack of physical activity may provide one of the most commonly thought influences in RMR decreasing with aging, it is also suggested that the aging and elderly have issues with overeating or undereating, difficulty chewing, polypharmacy (i.e., prescribed and taking multiple medications), living alone, and low income (Blanc et al., 2004). Many older individuals are facing these issues which could lead to further problems with metabolism. Since it is thought that by 2040 20% of Americans will be 65 years of age or older, it is important to determine how this population can continue to live a healthy lifestyle with as few chronic diseases as possible (Blanc et al., 2004). Additionally, with the Baby Boomers advancing in age, it is necessary to determine how monitoring RMR can be used to prevent chronic diseases. The health care industry (e.g., practitioners, dieticians, etc.) may not be ready for such an increase in chronic diseases and the effects these may have on a larger population of Americans. It is important to determine whether a lack of physical activity is truly a main cause of RMR decreasing with age, or if other factors are also of concern to provide individuals with successful interventions.

Purpose of the Study

The purpose of this study was to determine if level of physical activity correlated with RMR in an older population.
Significance of the Study

The significance of the study was to determine if physical activity affected RMR in older individuals. If a relationship existed, physical activity and RMR could be variables that professionals (physicians, exercise physiologists, etc.) observe in older populations.

Hypotheses

It was hypothesized that a higher physical activity level would be related to a higher RMR. Additionally, it was also hypothesized that participants with lower percentage body fat, abdominal diameter, and waist and hip measurements would also have a higher RMR.
CHAPTER II
LITERATURE REVIEW

Introduction

Resting metabolic rate (RMR) has been measured in various populations with different experimental designs in order to determine factors that influence RMR. Cross-sectional and intervention studies and measuring currently active older individuals have been used to better understand why RMR may decrease in aging individuals. Researchers have found relationships between both physical activity and FFM to RMR, but due to differences in experimental design, physical activity and FFM did not always increase RMR. Additionally, many devices that measure RMR have been tested to determine the best method of assessing this variable. The BodyGem and MedGem (“sister” resting metabolic rate hand-held devices) have been studied recently to determine if this new, convenient, easy-to-use, portable device is reliable and valid.

Relationship between Physical Activity and Resting Metabolic Rate

Physical activity may be the largest contributor to RMR. The majority of studies that focus on the relationship of physical activity to RMR have reported a positive correlation between these variables (Gilliat-Wimberly et al., 2001; Byrne & Wilmore, 2001; Campbell et al., 1994; Hunter, Byrne, Gower, Sirkul & Hills, 2006). In a population where RMR typically decreases after 40 years of age, it is necessary to determine if this is consistent for all individuals. The concept that physical activity prevents the risk of weight gain and loss of FFM has been reported in many of the following studies.
Cross Sectional Studies

A popular method of observing change in RMR in aging individuals is to compare older adults to their younger counterparts. Whether comparing sedentary young and older individuals or physically active young and older individuals, this method provides insight in the changes that may occur as an individual ages.

Younger (19-36 years old; 27 ± 1 years; n=39) and older (52-75 years old; 63 ± 1 years; n=32) local runners and triathletes were studied to determine if there was a difference between RMR for the age groups (Van Pelt et al., 2001). Additionally, there was a sedentary younger group (26 ± 1 years; n=32) and sedentary older group (62 ± 1 years; n=34) that the physically active groups were compared to. The results of this study were that older men, regardless of activity level, had RMRs lower than their younger counterparts (Van Pelt et al., 2001). However, when younger and older men were matched for exercise volume there was no difference in RMR between the groups (Van Pelt et al., 2001). The authors suggest that men who are able to maintain an exercise volume throughout life have a better chance of maintaining their RMR and body weight as they get older. Therefore, RMR does not have to decrease with aging.

Visser et al. (1995) measured energy expenditure of different age groups to determine the differences between young (20-33 years old; men: 27 ± 2 years, women: 23 ± 2 years; n=56) and elderly (63-87 years old; men: 73 ± 6 years, women: 72 ± 5 years; n=103) subjects. The objective was to determine whether there was an age effect even with a regular physical activity routine. Subjects completed a questionnaire that determined whether they were to be considered sedentary, moderately active, or active. Once the subjects were placed into groups, they were tested on RMR and diet induced thermogenesis. The authors found that overall, RMR is lower in elderly subjects compared with young subjects regardless of activity level (Visser et al., 1995).
They also found that there was not a distinct relationship between physical activity level and RMR and diet induced thermogenesis in any of the groups (Visser et al., 1995). One limitation of this study was that the physical activity questionnaire was different between the young and elderly groups. The elderly group had a questionnaire that had more “around the house” activities which may not be as physically taxing as moderate to vigorous exercise. Regardless, the results still showed the lack of relationship between physical activity level and RMR and diet induced thermogenesis.

These studies need to be examined closely when continuing RMR research. Different methodologies between age groups may affect the results of the study.

**Intervention Studies**

The use of interventions when measuring RMR is important because researchers are able to determine whether RMR increases with an increase in physical activity in individuals who are either sedentary or participate in low levels or amounts of physical activity. Resistance training and aerobic training have both been studied with the aging population to determine whether one type of exercise is more important or has more impact in maintaining RMR. Both have been shown to be successful by improving many variables related to RMR (e.g., weight loss, fat loss, or maintenance or increase in FFM).

**Resistance Training Interventions**

Campbell et al. (1994) found a positive relationship between RMR and resistance training in previously untrained elderly subjects (56-80 years old; 65 ± 2 years; n=12). The 14-week resistance training program consisted of measuring RMR prior to resistance training followed by
a prepared diet and exercise routine throughout the 14 weeks. The resistance training regimen consisted of subjects performing various exercises at 80% of their 1 RM while increasing workload every two weeks if necessary (i.e., based on strength gains). Throughout the intervention, subjects were given an additional amount of protein to make up for the energy expenditure of the resistance training. After the program was completed, RMR was measured again. RMR increased with the progressive resistance training program. When RMR was adjusted for FFM, RMR was increased, but not significantly. Overall, the authors found resistance training to be an appropriate intervention technique for healthy older adults to increase their energy expenditure and use toward weight maintenance programs. Additionally, Campbell et al. (1994) suggested that the increase in RMR was not due to an increase in total FFM, but to the increase in metabolic activity of the FFM.

Women 65 years old and older (72 ± 5 years; n=51) with coronary heart disease (CHD) were separated into a resistance training group and a control group to determine if a particular mode of exercise affected RMR, total energy expenditure, and strength. Since body weight, body composition, physical function, and overall metabolism may be affected by CHD, Ades, Savage, Brochu, Tischler, Lee & Poehlman (2004) wanted to determine if long term effects of physical activity had any influence on these variables. The resistance training group met three times per week for six months. Subjects began weight training at 50% of their 1-RM and gradually increased to 80% of their 1-RM (Ades et al., 2004). After the intervention, the women in the resistance training group showed improvements in RMR, total energy expenditure and strength even though they were frail (Ades et al., 2004). The conclusion of this study was that although these subjects already had a chronic disease, they may have improved other conditions, such as arthritis and sarcopenia that would prevent them from developing other debilitating signs or
symptoms. The improvement in the frail women could also increase mobility and overall energy expenditure leading to a decreased chance of developing obesity, Type 2 diabetes, and other chronic diseases. The authors suggested a program similar to the resistance training program utilized in this study because it could lead to an increased daily caloric expenditure and improved walking endurance and physical functioning, all of which directly or indirectly relate to physical activity and therefore, could increase RMR.

Byrne and Wilmore (2001) investigated two different forms of exercise training to determine if RMR was affected. The subjects were obese women (38 ± 0.9 years; n=28) who were separated into either a resistance training group or a resistance training with walking group. Both groups participated in the study for 20 weeks. The purpose for the resistance training group was to perform high intensity exercises to increase strength and FFM. The objective for the resistance training plus walking group was to increase strength, FFM, and aerobic capacity. The resistance training group had a significant increase in RMR, while the resistance training with walking group actually showed a decrease in RMR (Byrne & Wilmore, 2001). FFM was increased in both groups, which was the suggested reason for the increase in RMR in the resistance training group (Byrne & Wilmore, 2001). The overall conclusion was that the increase in FFM observed in the resistance training group was a factor in the increase in RMR.

**Aerobic Training Interventions**

In the past, researchers have decided to include both resistance training and aerobic training as an intervention. Few studies focus on aerobic training alone, causing a need for additional research in aerobic only training interventions.
Santa-Clara et al. (2006) found that a six-month moderate to vigorous-intensity cardiovascular exercise program for postmenopausal women (45-70 years old; African American: 56.3 ± 5 years, Caucasian: 58.6 ± 6.1 years; n=47) did not significantly change RMR. The previously sedentary subjects were divided into an exercise group and a sedentary group. A minimum of 3-4 days per week of cardiovascular training was required in which the exercise group worked their way up to sessions lasting 45-60 minutes. Although the authors explained that there was a difference with post-test values even when resting values were expressed per kilogram of body weight, the difference was small (Santa-Clara et al., 2006). In conclusion, the results of this study showed little relation between an endurance training program and an increase in RMR.

**Combined Resistance and Aerobic Training Interventions**

Gilliat-Wimberly et al. (2001) reviewed the effects that habitual exercise had on women 35-50 years old. Subjects were divided into an exercise (42 ± 3 years; n=18) or sedentary (42 ± 4 years; n=14) group depending on their physical activity over the previous five years. The exercise group was required to exercise for a minimum of six hours per week for the last five years (either resistance or aerobic training was accepted) and the sedentary group consisted of subjects who reported exercising less than two hours per week for the last five years. The women in the exercise group had a significantly higher RMR and lower levels of body fat than the sedentary women (Gilliat-Wimberly et al., 2001). These findings suggest that maintaining physical activity throughout life prevents a decrease in RMR observed in sedentary individuals.
Although Gilliat-Wimberly et al. (2001) found increases in RMR associated with combined training, the following researchers did not. Methodology is a main reason why such a difference was documented among these studies.

Thompson et al. (1997) found basal metabolic rate decreased slightly in all groups participating in a diet and exercise intervention (63-69 years old; 66 ± 3 years; n=40). The subjects of this study were divided into three groups, each with a specific purpose. One group decreased their energy intake by 500 kcals/day, another group decreased their energy intake by 700 kcals/day, and the last group decreased their energy intake by 500 kcals/day and participated in a physical activity program (resistance and aerobic training) throughout the 26-week program. The results of this study were that the diet and exercise group decreased the least in resting values which is thought to be the body’s way to protect energy expenditure values (Thompson et al., 1997). The groups in this study have been compared with subjects in similar studies. Other studies have found that with a decrease in energy intake and increase in physical activity, resting metabolic rates were maintained even in the aging population (Belko, Van Loan, Barbieri & Mayclin, 1987; Svendsen, Hassager & Christiansen, 1993). Studies involving a decrease in energy intake must be reviewed with the premise that a possible decrease in RMR will occur based on the lower number of calories the body needs to expend daily (i.e., a lower intake requires a lower need for expenditure). Campbell et al. (1994) increased energy intake (i.e., increased protein) after subjects began a strict diet and exercise intervention. The expenditure from exercise was increased and thus, energy intake was increased to maintain energy balance. Although resting values decreased slightly, a prolonged maintenance of RMR in this population after the intervention may prevent chronic diseases by decreasing the risk of developing overweight or obesity.
Delecluse et al. (2004) studied what type of exercise would be most beneficial for older men (n=79). The authors determined that even after dividing subjects into three distinct exercise groups, there was not a significant difference in RMR or FFM after the intervention. Men 55-75 years old were divided into one of four groups 1) control (61.5 ± 5 years; n=13), 2) endurance plus moderate resistance (ED+MR) (63.8 ± 4.8 years; n=22), 3) endurance plus low resistance (ED+LR) (63.7 ± 6 years; n=22), or 4) endurance plus endurance (ED+ED) (64.5 ± 5.3 years; n=22). The intervention groups exercised five days in a period of two weeks for a total of 20 weeks. After the intervention, there was not a significant difference in RMR found among the subjects (Delecluse et al., 2004). The authors explained that this may have been due to the lack of change in FFM in all the groups after the intervention.

Habitual Exercise

Some researchers decide to study individuals’ physical activity by measuring daily habitual exercise. This is a method for researchers to determine the amount and intensity of exercise individuals participate in based on common everyday activities. In the following studies, all researchers found daily activities to positively correlate with RMR.

Visser et al. (1995) decided to add to their cross-sectional study by comparing the highest and lowest levels of physically active elderly women (63-87 years old; 72 ± 5 years; n=103) since they had such a difference in body composition even after adjusting for FFM. The goal was to determine if the subjects with the highest and lowest level of activity in this age group showed significant differences in RMR. Isotope dilution was used in addition to hydrodensitometry to determine if physical activity and diet induced thermogenesis were factors. Additional methods of this study were discussed previously. When this correlation was completed, RMR and diet
induced thermogenesis were found to be significantly higher in the active group compared with the sedentary group (Visser et al., 1995).

Sergi et al. (2002) studied a group of underweight elderly subjects (70-88 years old; men: 79 ± 9 years, women: 80 ± 7 years; n=48) to determine functional status based on the influence of FFM. This study is unique in that underweight subjects are not studied as frequently as other groups. More often studied populations are healthy, elderly, young, or overweight and/or obese subjects. The individuals in the underweight group had a lower FFM (compared with a normal weight group), but FFM may not have been the only predictor in RMR (Sergi et al., 2002). Performance of activities of daily living were also a strong predictor of RMR and were independent from physical activity status (Sergi et al., 2002). Therefore, physical activity and performance of activities of daily living are contributors to RMR.

This study was similar to another that reviewed physical activity level and physical functioning in elderly subjects (60-74 years old; men: 71 ± 1 years, women: 70 ± 1 years; n=32; and >90 years old; men & women: 93 ± 1 years; n=22) to determine predictors of RMR and total energy expenditure (Frisard, Fabre, Russell, King, DeLany, Wood & Ravussin, 2007). Similar results were obtained that suggested that as physical activity levels decreased with age, there was also a decreased physical functionality relating to a decrease in RMR (Frisard et al., 2007).

_Aerobically Trained Individuals_

Although many of the studies on RMR focus on an intervention or comparing young to older individuals, Sullo et al. (2004) wanted to measure RMR in older athletes (average age of 65 years old; Group 1: 65 ± 2.6 years, Group 2: 65 ± 1.7 years, Group 3: 65 ± 0.5 years; n=18) who were already very physically active to determine whether varying aerobic capacity had any
influence on RMR. Older subjects were divided into groups based on their performance during a VO2max test completed as part of the study. Subjects with a VO2max >70 ml/kg/min were placed in Group 1, a VO2max of 55-70 ml/kg/min placed subjects in Group 2, and finally subjects with a VO2max <55 ml/kg/min were placed in Group 3. RMR was measured and the results showed men with the highest VO2max had the highest RMR. After reviewing body composition and finding little difference among the groups, the authors concluded that high levels of aerobic power are related to high levels of RMR without the influence of body composition (Sullo et al., 2004).

Fat-Free Mass is related to Resting Metabolic Rate

Many authors focusing on RMR not only measure RMR, but also FFM, based on the idea that FFM is metabolically active (Thompson et al., 1997). The following studies show how FFM is correlated with RMR. Some authors even suggest that FFM is the single most predictive component of RMR (Krems, Luhrmann, Strabburg, Hartmann & Neuhauser-Berthold, 2005; Luhrmann et al., 2001; Hurley & Roth, 2000; Aubertin-Leheudre et al., 2008).

Cross Sectional Studies

Bosy-Westphal et al. (2003) measured the FFM, RMR, bone mineral content, adipose tissue, total body water, body cell mass, extracellular mass, and the volume of organs in elderly (60-82 years old; 67.7 ± 6.6 years; n=26) and young (22-31 years old; 25.4 ± 2.4 years; n=26) subjects. Resting energy expenditure, when adjusted for FFM, was significantly lower in the elderly subjects. Furthermore, FFM accounted for the majority of resting energy expenditure (Bosy-Westphal et al., 2003). The many other variables measured in this study did not differ between
the young and elderly groups suggesting that the decrease in RMR in the elderly was related to a decline in FFM and perhaps, the changes in its metabolically active components (internal organs and skeletal muscle mass) (Bosy-Westphal et al., 2003).

A review of the literature by Wilson and Morley (2003) suggests that since there is such a variation among individuals as they age (>70 years old) and FFM accounts for this variation, age related sarcopenia may be the cause of a decreasing RMR with aging. Although a decrease in physical activity could increase sarcopenia, Sergi et al. (2002) also suggested that sarcopenia may be a determinant in resting energy expenditure in that it could decrease physical activity which would then influence the metabolic activity of the FFM in the body.

Resistance Training Interventions

The researchers who have conducted studies to determine whether FFM has an impact on RMR during resistance training interventions have actually found other variables that contribute to an increase in RMR. These factors are important to understand when comparing different studies.

Campbell et al. (1994) reviewed energy requirements in elderly subjects using a resistance training program to determine muscular strength, body composition, and energy balance. The authors did not see a change in FFM when reviewing the body density results, but did find a difference when examining the results of the total body water measurement (Campbell et al., 1994). This led the authors to believe that the increase in FFM and RMR was due to the metabolic activity of the lean tissue based on an increase in total body water without a change in metabolically active tissue mass (Campbell et al., 1994).
Ades et al. (2004) found an increase in RMR after a six month resistance training program in elderly women (>65 years old; 72 ± 5 years; n=51) without observing an increase in FFM. This led the authors to believe RMR may increase due to 1) skeletal muscle turnover which has been shown to increase after two weeks of resistance training or 2) an increase in sympathetic nervous system activation (plasma norepinephrine levels) (Ades et al., 2004). Even though body composition (body fat and BMI) measures did not change, RMR increased.

**Combined Resistance and Aerobic Training Interventions**

According to the previous studies, FFM is not always a predictor of RMR in individuals completing an intervention. Likewise, combined resistance and aerobic training research has suggested FFM is a predictor in some studies, but not in others.

The effects of a 20 week exercise program were reviewed in moderately obese women (38 ± 0.9 years; n=28) to determine if there was a difference in mode of training and RMR (Byrne & Wilmore, 2001). The subjects were divided into a resistance training group (n=10), a resistance training plus walking group (n=9), or control group (n=9). After the program, FFM was significantly higher in both groups (Byrne & Wilmore, 2001). RMR increased in the resistance training group, but decreased in the resistance training plus walking group (Byrne & Wilmore, 2001). The authors believed that the increase in RMR was related to the increase in FFM, and if it weren’t for heat acclimation in the resistance training plus walking group, RMR may have been different (Byrne & Wilmore, 2001).

Thompson et al. (1997) studied postmenopausal women (63-69 years old; 66 ± 3 years; n=40) who were required to follow a diet and exercise plan for 24 weeks. The subjects in this study were able to lose significant body weight and fat without decreasing their RMR significantly
The thought behind the significant weight and fat loss without a significant decrease in RMR was that there was a minimal decline in FFM which assisted in the maintenance of RMR values (Thompson et al., 1997). The importance of the findings in this study are that significant decreases in weight and fat loss may maintain RMR instead of decreasing it drastically if FFM can be maintained.

Delecluse et al. (2004) required older subjects (55-75 years old; control: 61.5 ± 5 years, ED + MR: 63.8 ± 4.8 years, ED + LR: 63.7 ± 6 years, ED + ED: 64.5 ± 5.3 years; n=79) to be randomly assigned into one of four groups (control, endurance plus moderate resistance training, endurance plus low resistance training, or endurance plus endurance) to determine which mode of exercise would promote the greatest health benefits. After the 20 week program was completed, the authors did find an increase in health benefits, but observed a lack of increase in RMR due to the finding that no change in FFM was observed in any of the groups (Delecluse et al., 2004).

**Literature on the BodyGem/Resting Metabolic Rate Device**

The use of hand-held portable metabolic devices for measuring RMR is a new procedure compared with metabolic carts and doubly labeled water methods. The BodyGem (Healthtech Inc., Golden, CO, USA) and MedGem (Healthtech Inc., Golden, CO, USA) have been developed to enhance the measurement of RMR in a way that the size of the equipment is small, portable, easy-to-use, and affordable (Melanson, Coelho, Tran, Haugen, Kearney & Hill, 2004). The reliability of the BodyGem and the MedGem (“sister” devices used for the same purpose) have been investigated.
Melanson et al. (2004) tested the reliability of the BodyGem against a metabolic cart (Sensormedics 2900, SM-2900) in 41 healthy adults (21-61 years old; men: 38 ± 12 years, women: 42 ± 11 years). Two trials for each piece of equipment were recorded. The BodyGem predicted subjects’ RMR to be significantly higher than the metabolic cart (Melanson et al., 2004). These results do not necessarily show inaccuracy of the device though. Since the subjects were required to hold the BodyGem up to their mouths while breathing into it, the researchers thought that there may be a higher energy requirement to hold the BodyGem in place as opposed to a metabolic cart in which the subject does not need to hold the equipment (Melanson et al., 2004). To determine if this was true, the subjects were asked to lie in a supine position under a ventilated hood canopy and hold the BodyGem to determine if the RMR was higher (Melanson et al., 2004). Consequently, there were no significant differences between the BodyGem and the metabolic cart under these conditions (Melanson et al., 2004). Both methods provided similar results in multiple trials showing that the reliability of the hand-held device is good. The conclusion was that with the reliability, accessibility, cost, size, self calibration, and ability to run on batteries, the BodyGem can be used in multiple settings from universities to health care providers (physicians, dieticians, exercise physiologists, etc.) (Melanson et al., 2004).

Compher et al. (2005) compared the BodyGem’s sister hand-held device; the MedGem, to a metabolic cart (Deltatrac, Sensormedics, Yorba Linda, CA, USA) to determine differences in reliability. The subjects (18-76 years old; 46.8 ± 15.1 years; n=24) in this study were patients in need of managing parenteral feedings (feedings directly to a vein) or gastrointestinal dysfunction (Compher et al., 2005). The importance of a device that is reliable is needed in this population because many times dramatic weight loss occurs (Compher et al., 2005). The patients completed two trials with the MedGem and one trial with the ventilated hood canopy (Deltatrac). When the
MedGem trials were compared, they were similar, but when they were compared with the Deltatrac they tended to be lower than the Deltatrac results (Compher et al., 2005). Unfortunately, the Deltatrac trials were only completed once and they could not be compared for within device reliability. Furthermore, the sample size was low and did not consist of healthy individuals which are many times the basis of studies. Also, the sample population was in a state in which they could not fast for the recommended 12 hours prior to RMR measurement (only fasted for 4 hours). In conclusion, the authors suggested that the MedGem is replicable and clinically acceptable, but lower when compared with the Deltatrac (Compher et al., 2005).

Fares, Miller, Masters & Crotty (2008) reviewed the validity and acceptability of the MedGem to a ventilated hood method in adults 65 years old and older (79 ± 11.6 years; n=48). They required the subjects to complete one trial with the ventilated hood and one trial with the MedGem. Results for this study determined that the MedGem does not accurately measure resting energy expenditure (overestimates by 30%) in this population (Fares et al., 2008). The authors explained that although there were many limitations, including the subjects need to hold the MedGem up for each trial, the MedGem is still not a valid device for this population (Fares et al., 2008). Unfortunately, the researchers in this study did not compare the reliability of the MedGem like Compher et al. (2005) having subjects hold the MedGem up under the canopy to compare results. Within device variability could not be observed with only one trial of each piece of equipment.

Summary

In conclusion, there is a great amount of research that supports physical activity and/or FFM in relation to a maintenance or increase in RMR. There is also research that does not support that
physical activity and/or FFM contribute to RMR and another factor must play into increasing
RMR if that is the goal. Consequently, the methodology of these studies need to be reviewed to
determine if all researchers are conducting research similarly. Essentially, additional research is
needed in this area based on the conflicting results found by many researchers.

In addition, further research needs to be conducted to validate the BodyGem hand-held
calorimeter. Previous pilot study data by Heitkamp, Darby, Mospan, Carels, & Berger (2008) has
shown that measures between the BodyGem and a mobile metabolic cart (OxyCon Mobile,
Viasys, Dublin, Ohio, USA) were not significantly different. The methods used in Heitkamp et
al. (2008) were the same methods used in the current study. On the other hand, the methods of
some research has led researchers to speculate how careful one must be when measuring RMR
with this piece of equipment. When there is an agreement between researchers on how to
properly utilize the BodyGem for RMR measures, results may mirror the outcome traditional
energy expenditure equipment (i.e., canopy, metabolic cart, etc.) produces.
CHAPTER III

METHODS

Subjects

Thirty apparently healthy low risk men and women aged 55-69 years of age (average age = 60 years old) were recruited for this study (American College of Sports Medicine, 2005). Subjects were excluded if they suffered from coronary heart disease, pulmonary diseases, cancer, diabetes, were on medications that may alter the results of resting metabolic rate (see Appendix A), were on a diet or were current smokers. Flyers were distributed and posted in local hospitals, senior centers, buildings at Bowling Green State University and recreation centers. Additionally, subjects were recruited through relatives and other studies conducted by the School of Human Movement, Sport, and Leisure Studies at Bowling Green State University. Subjects were advised to call if interested in the study. An explanation of the study was provided upon first phone contact. Participants were asked to report to the Exercise Physiology Laboratory at Bowling Green State University to receive instructions for preparation (see Appendix B) prior to data collection, and complete an informed consent (see Appendix C) and Health History Questionnaire (see Appendix D). If subjects lived further away, the primary investigator traveled to their home. The study was approved by the Human Subjects Review Board at Bowling Green State University prior to data collection.

Resting Metabolic Rate

Testing took place between 5:00 am and 11:00 am. Resting metabolic rate (RMR) was measured using the BodyGem handheld device (BodyGem™, HealtheTech, Inc., Golden, CO, USA). The subjects were asked to fast for 12 hours, and refrain from any form of tobacco for 2
hours and any type of exercise or physical activity that causes shortness of breath or physical exertion at least 24 hours prior to testing. The subjects were also instructed to avoid showering, brushing their teeth and hair, and walking further than to their car and into the building on the morning of their testing.

Body height and weight were measured using a standard physician’s scale. Body height was measured to the nearest 0.1 cm and body weight was measured to the nearest 0.1 kg. These measures were used to calculate body mass index. The equation: weight (kg)/height (m²) was used. These measurements were taken prior to RMR measurements as required for the BodyGem software to provide accurate results.

Subjects were asked to lie in a supine or semi-supine position on a reclining chair or gurney for 20 minutes prior to measuring RMR. After the rest period, the subject was handed the BodyGem, placed noseclips over their nostrils, and began to breathe normally into the mouthpiece of the BodyGem while in the resting position. The BodyGem records constant values and calculates RMR over a 5-10 minute period. Immediately following the first measurement of RMR, the subject completed a second measurement with the BodyGem to compare reliability of the device. During data collection, a few of the subjects felt uncomfortable completing a second trial with the BodyGem so the first trial results were used in analyses. For those who participated in a second trial of RMR, a test-retest reliability was calculated (r = .842).

Anthropometric Measures

Excluding height and weight, anthropometric measures were taken following RMR measurements. Body composition was measured using skinfold calipers. Participants were asked to stand up straight while measurements were taken on the right side of their body. For women,
the three sites where subcutaneous fat was measured were the triceps, suprailiac, and thigh. For male subjects, the chest, abdomen, and thigh were measured. The researcher took three measurements at each site on each participant, and the median for the result was used for calculations. An age appropriate equation was used to determine overall body fat percentage (see Appendix E) (Jackson & Pollack, 1985).

Waist and hip measurements were measured in centimeters using a Gulick tape and utilized to determine abdominal adiposity. Waist measurements were measured around the smallest point of the subject’s torso. Hip measurements were measured around the largest protrusion around the subject’s buttocks (American College of Sports Medicine, 2005). Abdominal diameter was measured with two yardsticks and a level. The subject was asked to lie supine on a table while a yardstick was placed on top of their umbilicus with the level on it. The other yardstick was held vertically from the top of the table to the height of the other yardstick. The subject was asked to inhale, exhale, and hold the exhalation for a couple of seconds for the researcher to read the height in inches the umbilicus was from the tabletop (Parr & Haight, 2006). Since data collection took place away from the Exercise Physiology Laboratory for a number of subjects and large tables were not always available, this measurement was excluded for some subjects.

Accelerometer Data

After RMR and body composition measures were obtained and recorded, subjects were given an accelerometer. Subjects were instructed to wear the Lifecorder EX accelerometer (New Lifestyles, New Lifestyles, Inc., Lee’s Summit, MO, USA) for two weeks. Subjects were asked to refrain from altering their physical activity or diet in any way while participating in the study. Subjects were not responsible for recording their steps taken per day since the accelerometer
saved daily values. Additionally, requiring subjects to record their steps taken may lead to additional activity by the subjects that is not usually performed. If subjects’ regular physical activity included swimming, they were asked to record days and amount of time spent swimming since the accelerometer cannot be worn in the water. At the completion of two weeks, the subjects returned to the Exercise Physiology Laboratory so that the researchers were able to retrieve the accelerometers and obtain the daily values.

Statistics

Pearson correlation coefficients (Pearson $r$) were completed to determine the relationship between RMR, the criterion (dependent variable), and other independent variables (i.e., age, height, weight, etc.). The probability was set at $p < 0.05$. Furthermore, a coefficient of determination ($r^2$) was calculated to determine the meaningfulness of $r$; “$r^2$ indicates the portion of total variance in one measure that can be explained or accounted for by the variance of the other measure” (Thomas, Nelson & Silverman, 2005, p. 139). Power and effect size were then calculated. “Power is the probability of rejecting a false null hypothesis” (i.e., correct rejection of the null hypothesis) (Thomas, Nelson & Silverman, 2005, p. 116). “Effect size is the difference between the means divided by the standard deviation” (Thomas, Nelson & Silverman, 2005, p. 115). Finally, a multiple regression was used to determine which variables (i.e., anthropometric variables or physical activity level variables) were the best predictors of RMR. All independent variables were entered into the multiple regression. Based on tolerance and beta weights, final predictor variables were selected. The final multiple regression equation used four independent variables to predict the dependent variable, RMR.
CHAPTER IV

RESULTS

Participant Characteristics

Values for all of the independent variables are shown below in Table 1. There were only two significant differences between men and women. Women were shorter and had a higher percentage of body fat when compared to the men. Since the sample size was small when separating the group by genders, results determined by gender were not reported. Therefore, all the results were reported for the group as a whole.

Table 1: Participant Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men (n=18)</th>
<th>Women (n=12)</th>
<th>All (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMR (calories)</td>
<td>1510 ± 359</td>
<td>1212 ± 325</td>
<td>1391 ± 371</td>
</tr>
<tr>
<td>Age (years)</td>
<td>59.6 ± 3.6</td>
<td>60.0 ± 3.6</td>
<td>59.8 ± 3.5</td>
</tr>
<tr>
<td>Height (inches)***</td>
<td>70.4 ± 2.3</td>
<td>65.3 ± 2.3</td>
<td>68.4 ± 3.4</td>
</tr>
<tr>
<td>Weight (lbs.)</td>
<td>205.5 ± 43.6</td>
<td>154.3 ± 26.4</td>
<td>185.0 ± 45.0</td>
</tr>
<tr>
<td>BMI (kg·m(^{-2}))</td>
<td>29.3 ± 6.4</td>
<td>25.4 ± 4.0</td>
<td>27.7 ± 5.8</td>
</tr>
<tr>
<td>Percent Body Fat**</td>
<td>20.9 ± 4.9</td>
<td>31.4 ± 5.6</td>
<td>25.1 ± 7.3</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>100.5 ± 12.9</td>
<td>81.9 ± 6.8</td>
<td>93.1 ± 14.2</td>
</tr>
<tr>
<td>Hip (cm)</td>
<td>109.7 ± 14.1</td>
<td>104.5 ± 9.9</td>
<td>107.6 ± 12.7</td>
</tr>
<tr>
<td>Waist to Hip Ratio (cm)</td>
<td>.91 ± .05</td>
<td>.78 ± .04</td>
<td>.86 ± .08</td>
</tr>
<tr>
<td>Abdominal Diameter (inches)</td>
<td>9.1 ± 2.8*</td>
<td>8.3 ± .95</td>
<td>8.7 ± 2.1</td>
</tr>
<tr>
<td>Daily Steps (#)</td>
<td>7179.2 ± 3129.8</td>
<td>6969.1 ± 2166.2</td>
<td>7095.1 ± 2744.6</td>
</tr>
<tr>
<td>Physical Activity (Calories)</td>
<td>265.7 ± 119.7</td>
<td>224.6 ± 74.9</td>
<td>249.3 ± 104.6</td>
</tr>
<tr>
<td>Physical Activity (Minutes)</td>
<td>16.1 ± 12.4</td>
<td>18.0 ± 11.9</td>
<td>16.9 ± 12.0</td>
</tr>
</tbody>
</table>

*n=15; see text for explanation
**p≤0.05 between men and women
***p≤0.01 between men and women
Correlations

Resting Metabolic Rate

Resting metabolic rate was significantly correlated with every variable except percent body fat, physical activity calories, and physical activity minutes (see Table 2). Correlation matrices for men and women separately are shown in Appendices F and G.

Anthropometric Measures

As expected, many of the anthropometric measures were significantly correlated with each other (Table 2). Height, weight, and BMI were correlated. Measures of abdominal obesity such as waist and hip circumference and abdominal diameter also were correlated. Additionally, percent body fat was correlated with a number of variables including waist to hip ratio and abdominal diameter. Interestingly, hip circumference was not significantly correlated with waist to hip ratio.

Accelerometer Data

Daily steps were significantly negatively correlated with RMR, BMI, percent body fat, hip circumference, and abdominal diameter among the participants (i.e., higher daily steps = lower BMI, percent body fat, etc.). Physical activity calories were significantly correlated with physical activity minutes. Conversely, physical activity calories did not correlate with any of the anthropometric or physiological variables. Physical activity minutes were significantly positively correlated with age and percent body fat.
### Table 2: Correlation Matrix for All Participants

<table>
<thead>
<tr>
<th></th>
<th>RMR</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
<th>BMI</th>
<th>Body Fat</th>
<th>Waist</th>
<th>Hip</th>
<th>Ratio</th>
<th>Abdominal Diameter</th>
<th>Daily Steps</th>
<th>PA Cals</th>
<th>PA Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMR</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.00</td>
<td>0.378</td>
<td>0.634</td>
<td>0.540</td>
<td>0.589</td>
<td>0.509</td>
<td></td>
<td></td>
<td></td>
<td>-0.423</td>
<td>-0.412</td>
<td>0.136</td>
<td>0.142</td>
</tr>
<tr>
<td>Height</td>
<td>1.00</td>
<td>0.218</td>
<td>0.557</td>
<td>0.203</td>
<td>-0.505</td>
<td>0.541</td>
<td></td>
<td></td>
<td></td>
<td>0.481</td>
<td>-0.212</td>
<td></td>
<td>0.013</td>
</tr>
<tr>
<td>Weight</td>
<td>1.00</td>
<td>0.924</td>
<td>0.919</td>
<td>0.890</td>
<td>0.399</td>
<td>0.745</td>
<td>-0.282</td>
<td></td>
<td></td>
<td>0.123</td>
<td>0.219</td>
<td>0.211</td>
<td>0.193</td>
</tr>
<tr>
<td>BMI</td>
<td>1.00</td>
<td>0.837</td>
<td>0.928</td>
<td>0.800</td>
<td>0.233</td>
<td>0.812</td>
<td>0.444</td>
<td>-0.444</td>
<td></td>
<td>0.045</td>
<td>0.045</td>
<td>0.064</td>
<td>0.107</td>
</tr>
<tr>
<td>Body Fat</td>
<td>1.00</td>
<td>0.389</td>
<td>0.389</td>
<td>0.889</td>
<td>0.324</td>
<td>-0.379</td>
<td>0.047</td>
<td>0.324</td>
<td>0.104</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist</td>
<td>1.00</td>
<td>0.779</td>
<td>0.660</td>
<td>0.777</td>
<td>0.347</td>
<td>-0.379</td>
<td>0.753</td>
<td>0.034</td>
<td>0.268</td>
<td>-0.026</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Hip</td>
<td>1.00</td>
<td>0.047</td>
<td>0.660</td>
<td>0.777</td>
<td>0.553</td>
<td>0.034</td>
<td>0.324</td>
<td>0.088</td>
<td>0.342</td>
<td>0.094</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdominal Diameter</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.513</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily Steps</td>
<td>1.00</td>
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<td></td>
<td></td>
<td></td>
<td>0.402</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PA Cals</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PA Min</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Regression Analysis

The regression analysis provided a number of variables for the group that were significant to use in a prediction equation of RMR. The following table shows the tolerance level of each variable.

Table 3: Regression for All Participants

<table>
<thead>
<tr>
<th>Model 1</th>
<th>Tolerance</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant (-1530.625)</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>.234*</td>
<td>45.563</td>
</tr>
<tr>
<td>Height</td>
<td>.003</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>Percent Body Fat</td>
<td>.106*</td>
<td>3.992</td>
</tr>
<tr>
<td>Waist Circumference</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>Hip Circumference</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>Waist to Hip Ratio</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>Abdominal Diameter</td>
<td>.012</td>
<td></td>
</tr>
<tr>
<td>Daily Steps</td>
<td>.070</td>
<td></td>
</tr>
<tr>
<td>Physical Activity Calories</td>
<td>.203*</td>
<td>.735</td>
</tr>
<tr>
<td>Physical Activity Minutes</td>
<td>.216*</td>
<td>-5.182</td>
</tr>
</tbody>
</table>

*tolerance level of .1 or higher

The regression was calculated with only the variables demonstrated to have a tolerance of 0.1 or higher to provide the prediction equation below for the group:

\[ RMR = -1530.625 + 45.56 \text{ (age)} + 3.992 \text{ (percent body fat)} + .735 \text{ (physical activity calories)} - 5.182 \text{ (physical activity minutes)} \]
Selected independent variables (i.e., age, height, weight, etc.) were used in a multiple regression to determine which ones explained the most variance to predict RMR. Age, percent body fat, physical activity calories, and physical activity minutes best predicted RMR. Although many variables may have had a relationship with RMR, in the present study these four explained the most variance in RMR. Age, percent body fat, physical activity calories, and physical activity minutes explained 17.6% of the variance ($R^2 = .176; R = .420$). (The multiple regression equation model was not significant; $p = .283$). The standard error of the estimate was equal to 363 kcals. Although the model was not statistically significant ($p = .283$), it did provide the variables that were most predictive of RMR.
CHAPTER V

DISCUSSION

In this investigation, RMR was not significantly correlated with physical activity level (physical activity calories and physical activity minutes) as was hypothesized. RMR did correlate with daily steps, but the correlation was negative suggesting that a higher number of daily steps correlates with a lower RMR. These findings disagree with many authors that suggest physical activity has a positive correlation with RMR (Gillilliat-Wimberly et al., 2001; Byrne & Wilmore, 2001; Campbell et al., 1994; Hunter et al., 2006). Although the findings of this study did not necessarily agree with previous research, the negative correlations that occurred between daily steps and various anthropometric measures provides an insight to how physical activity may decrease these measures and health risk factors associated with them.

Additionally, when analyzing the group using the multiple regression analysis, it was found that four variables were significant in determining a prediction equation for RMR. Age, percent body fat, physical activity calories and physical activity minutes were found to be significant, as shown in the following equation:

\[ RMR = -1530.625 + 45.56 \text{ (age)} + 3.992 \text{ (percent body fat)} + 0.735 \text{ (physical activity calories)} - 5.182 \text{ (physical activity minutes)} \]

When analyzing daily steps, a negative correlation occurred with many of the variables including BMI, percent body fat, hip circumference, and abdominal diameter. The negative correlations between these variables suggest that as daily steps increase, BMI, percent body fat, hip circumference, and abdominal diameter decrease. Although weight was not significantly correlated with daily steps, it is still important to acknowledge the negative correlation between the variables. The negative correlations between these variables are important in this field.
because possible weight loss and fitness goals may be obtained by recording daily steps. Weight, BMI, percent body fat, hip circumference, and abdominal diameter are all measurements that are used by professionals to determine an individual’s health status. If the simple task of walking or tracking steps taken per day could be used by professionals, a program like the 10,000 steps per day could be utilized more frequently for health gains. A decrease in cardiovascular disease risk factors would benefit millions in the country. The findings of these variables agree with many previous intervention studies (Byrne & Wilmore, 2001; Gilliat-Wimberly et al., 2001; Ades et al., 2004; Campbell et al., 1994) because activity was shown to be correlated with many anthropometric parameters that were measured.

Physical activity calories and physical activity minutes did not correlate with as many variables as expected. It was expected that more calories utilized during physical activity (shown through moderate to vigorous activity by the accelerometer) and more time spent in physical activity would correlate negatively with variables like weight, BMI, waist to hip ratio, etc. Although there was a significant correlation between physical activity minutes and percent body fat, it wasn’t negative suggesting that more activity minutes may correlate with a higher percent body fat. These findings are unlike others that suggest a physical activity routine may decrease percent body fat (Byrne & Wilmore, 2001). This result may have occurred due to the fact that physical activity minutes were only reported during moderate to vigorous activity and many of the participants had low amounts of physical activity minutes despite their daily steps. Thus, the reported accelerometer data did not truly reflect total daily physical activity.

Additionally, one correlation that was expected, between physical activity calories and physical activity minutes, was significant. As shown in Table 2, physical activity calories and physical activity minutes were positively correlated and demonstrated the expected relationship.
This correlation supports the point that participation in physical activity expends calories causing possible weight loss and improvement of a healthy lifestyle.

RMR was not significantly correlated with percent body fat which was unexpected. Unlike other studies (Campbell et al., 1994; Byrne & Wilmore, 2001; Thompson et al., 1997), a significant correlation was not found. While many authors have reported a relationship between RMR and percent body fat, other authors have stated that RMR may increase without a significant decrease in percent body fat (Ades et al., 2004).

Although percent body fat was not correlated with RMR, it was correlated with many of the other variables. The variable that percent body fat related to in past studies was daily steps. In a study by Byrne and Wilmore (2001), they required their participants to participate in a resistance training and walking intervention. When the intervention was completed, the results showed an increase in FFM. Results from the current study also suggest that a higher number of daily steps correlates with a lower percent body fat as was also shown by Byrne and Wilmore (2001). Other variables such as waist to hip ratio and abdominal diameter were expected to be correlated with percent body fat because these are main areas of measurement when determining percent body fat (by use of skinfold calipers).

Although significant correlations between RMR and many other variables measured were recorded, some of the variables showed a much higher percentage of variance that was being explained by the relationship between that variable and RMR. Weight ($r^2=.40$), BMI ($r^2=.29$), waist circumference ($r^2=.34$), hip circumference ($r^2=.25$), and abdominal diameter ($r^2=.40$) were the variables that showed the highest percentage of explained variance while the other variables showed percentages between 11%-19%. Although waist and hip circumferences and abdominal diameter explained a greater percentage of the variance in RMR, the relationship was a positive
correlation suggesting that the higher the RMR, the higher the waist and hip circumferences and abdominal diameter. This finding agrees with the hypothesis that there is a correlation, but disagrees because the correlation is positive.

Weight and BMI were expected to be correlated with many of the anthropometric measures that were obtained. Weight and BMI were positively correlated with RMR, waist and hip circumference, waist to hip ratio, and abdominal diameter, which was not unexpected. In fact, almost all of these variables showed high percentages of variance when analyzed with weight and BMI respectively (BMI: $r^2 = .85$, waist circumference: $r^2 = .84$, hip circumference: $r^2 = .79$, and abdominal diameter: $r^2 = .55$; Weight: $r^2 = .85$, waist circumference: $r^2 = .70$, hip circumference: $r^2 = .86$, abdominal diameter: $r^2 = .65$). Body weight is a factor in many of these variables when they are measured (i.e. BMI). Additionally, it is important to acknowledge that as weight and BMI increase, so may the other variables that are correlated. The correlation between these variables may assist professionals in determining possible risk factors of cardiovascular disease (e.g., if BMI increases, a professional may decide to also measure waist to hip ratio).

As expected, age was significantly related to RMR and abdominal diameter. In this study, however, an older age correlated with a higher RMR. This may be due to the moderate to vigorous physical activity levels of some of the older participants in this study. The correlation between age and RMR disagrees with previous research that states there is a decline in RMR as an individual ages (Visser et al., 1995). Even after reviewing activity levels of both older and younger subjects, Visser et al. (1995) found that overall, RMR is lower in elderly subjects compared with young subjects regardless of activity level. A lower RMR due to aging may contribute to weight gains in the abdominal region. This may help explain the correlation between age and abdominal diameter. Aubertin-Leheudre et al. (2008) explained that aging may
be associated with a decline in physical activity and FFM which may lead to an increase in fat mass that includes abdominal fat.

Limitations

There were a few limitations to this study that should be discussed. The main limitation that could have caused discrepancies was that many participants did not feel comfortable lying flat on a gurney and preferred to recline in a chair while performing the RMR measurement with the BodyGem. This caused participants to hold the BodyGem up to their mouths in order to complete the measurement and this has been shown to increase RMR (Melanson et al., 2004). Although the participants may not have balanced the BodyGem in their mouths, they found positions that were the most comfortable to perform the measurement.

Furthermore, many of the participants complained the BodyGem made them feel claustrophobic, that they developed dry mouth, or couldn’t swallow saliva during the measurement. Feeling claustrophobic or having a difficult time breathing into the BodyGem could skew the results to show an inaccurate value based on individual breathing patterns and anxiety levels. However, after participants performed the first measurement, they did note that it “became easier”.

The accelerometer posed an issue for some participants who regularly participate in activities in which the accelerometer does not accurately record movement such as riding a bike. Unfortunately, the accelerometer does not record the activity of cycling as well as it does ambulatory activities. Additionally, several participants reported regular swimming routines. This activity was not recorded on the accelerometer. Participation in these activities led to an underestimation of some of the participants’ activity levels.
Future Research

Future research may include a few variables this study was not able to measure or control. A future step researchers could take for studies similar to this one would be to require the participants to record what they eat every day prior to accelerometer use and while wearing the accelerometer (for the two week period). Additionally, physical activity prior to and during the study could also be recorded.

Another suggestion for future research may be to include low intensity activity as part of the physical activity minutes and physical activity calories. Many participants had careers in which they walked all day but the activity was not recorded under physical activity minutes or physical activity calories because the activity was not moderate to vigorous activity. It would be interesting to compare results to determine if physical activity minutes and physical activity calories would be significantly correlated with more variables.

Finally, additional research using the same equipment is needed in this field to understand how it can be utilized in populations that would like to change their lifestyles, enhance their current exercise program, or learn about their physical activity routine. There is much research published on RMR, but only a limited amount using the BodyGem. In addition, there are no studies that the primary investigator is aware of that used an accelerometer to compare physical activity to RMR as measured by the BodyGem.

Conclusions

Although RMR was not correlated with physical activity level and positively correlated with percent body fat, abdominal diameter, and waist and hip circumferences, many other correlations between the variables were found that could increase knowledge in this field. The negative
correlation that occurred between number of daily steps and BMI, percent body fat, hip measurements, and abdominal diameter suggests that a higher physical activity level could help individuals decrease their BMI, percent body fat, hip circumferences, and abdominal diameter. These are all measures that predict cardiovascular disease. Additionally, many variables that were expected to be related to each other did show a correlation like weight, BMI, percent body fat, waist and hip circumferences, waist to hip ratio, and abdominal diameter. Many of the findings provided additional suggestions for lifestyle changes that may be implemented by health care professionals.
REFERENCES


Campbell, W.W., Crim, M.C., Young, V.R. & Evans, W.J. (1994). Increased energy requirements and changes in body composition with resistance training in older adults. 


APPENDIX A:

METABOLISM INCREASING MEDICATIONS
List of Metabolism Increasing Medications:

- Ephedrine
- Adderall
- Dexedrine
- Meridia
- Adipex
- Synthroid
- Levoxyl
- Levothroid
- Armour Thyroid
- Ma Huang
- White Willow
- Guarana
- Ginseng ≥ 100mg
- Caffeine and products containing caffeine

Sources: (Mandy Yates, RpH) (Todd Keylock, Ph.D.)
APPENDIX B:

INSTRUCTIONS GIVEN PRIOR TO DATA COLLECTION
Instructions Prior to Data Collection

These are the basic instructions for the day prior to when you come in for testing. Please follow the suggested recommendations and call if you have any questions. I appreciate your participation in this study! Thank you and see you soon!

1) **Fast** for 12 hours prior to testing.
2) You may and are encouraged to **drink water** during the fasting period (please refrain from any other drinks, i.e. soda, juice, flavored water, coffee, tea, etc.)
3) **Refrain** from the following:
   - **Physical activity** that causes a shortness of breath or physical exertion for 24 hours prior to testing.
   - **Tobacco and Caffeine** 2 hours prior to testing.
   - **Activity** the morning of testing.
4) Also, in order to come in a rested manner please **avoid** on the **morning of your testing**:
   - **Showering**
   - **Brushing teeth or hair**
   - **Walking further than to your car and into the building**
5) Please **do not alter your diet** prior to testing. Attempt to eat/drink as you normally do.
6) Remember to **bring in your Informed Consent Form and Health History Questionnaire completed** on the morning of your testing.
7) Please **wear comfortable clothing**. Shorts and a t-shirt is recommended based on the measurements that will be taken (there are restrooms if you need to change into these clothes or have to change for work. There are also locker rooms in the building for showering if you need them.).
8) I will provide **food and drink after testing**.
APPENDIX C:

INFORMED CONSENT FORM
The Comparison of Resting Metabolic Rate to Daily Physical Activity
Measured by an Accelerometer in Adults Aged 55-69 Years
Jessica E. Mospan, Graduate Student
Bowling Green State University

Informed Consent Form

You are invited to be in a research study on resting metabolic rate and physical activity. As part of my work on my Masters degree in the Department of Kinesiology, I am conducting a research study of adults aged 55-69 years looking at their level of physical activity and how many calories they burn at rest daily.

This study is being conducted for my thesis. The purpose of this study is to see if physical activity affects the amount of calories you burn while at rest (resting metabolic rate). The study will take about 2 weeks of your time, but you will only need to come to Bowling Green State University 2 times. The majority of the study will take place at your home while you do normal everyday activities.

Procedures For this study, you will be asked to come to the Exercise Physiology Lab between 7:00 am and 11:00 am. You will be asked to fast for 12 hours and refrain from caffeine and tobacco for 2 hours. You will also be instructed to refrain from any type of exercise or physical activity that causes shortness of breath at least 24 hours prior to testing. You will also be instructed to avoid showering, brushing your teeth and hair, and walking further than to your car and into the building on the morning of your testing. You will be asked to rest in a reclining chair for 20 minutes before measuring resting metabolic rate (RMR). After the rest period, you will be handed the BodyGem (a handheld piece of equipment), place a noseclip over your nostrils, put the mouthpiece of the BodyGem in your mouth, and normally breathe into the mouthpiece. Your metabolism will be recorded over a 5-10 minute period. After the first measurement, you will be asked to do a second measurement to compare reliability of the device.
Body height and weight will be measured using a scale. Body fat will be measured by gently pinching three areas where fat normally accumulates. The three areas that will be pinched on men are the chest, abdomen, and thigh. The three areas that will be pinched on women are the tricep (back of upper arm), above the hip, and thigh. Waist and hip measurements will be measured using a measuring tape to determine abdominal fat. Abdominal diameter will be measured by having you lay on a table while using yardsticks to measure from the table top to your belly button.

After the measurements are taken, you will be given an accelerometer. An accelerometer is similar to a pedometer in that it measures physical activity (total steps, calories burned, etc.). You will be instructed to wear the accelerometer all day, every day on your waist for two weeks. Do not change anything about your physical activity during these two weeks. You do not have to record anything from the accelerometer because it records it by itself. At the end of the two weeks, you will return to the Exercise Physiology Lab with your accelerometer so that we can record the information.

Your initial visit will take about 1 to 1½ hours. Your second visit, when you return your accelerometer, will take 5-10 minutes.

**Risks** The anticipated risks to you are no greater than those normally encountered in daily life. Please let me know if you are unable or do not feel comfortable fasting for 12 hours.

**Benefits** You may benefit from this study in the following ways: 1) will be able to see how much physical activity you actually participate in (using the accelerometer); 2) will learn about RMR and how it effects obesity and other chronic diseases; 3) may be able to compare your level of physical activity to your RMR value; and 4) may use your data in order to change unhealthy lifestyle behaviors.

**Confidentiality** Information you provide will remain confidential and your identity will not be revealed. All forms and data sheets will locked in a cabinet in the lead investigator’s office. Also, subjects will only be identified on forms and data sheets by an identification number.

This study is completely voluntary. You may withdraw your consent or participation at any time from this study without penalty.
If you have questions about the conduct of this study or your rights as a research participant, you may contact the Chair of Bowling Green State University's Human Subjects Review Board at (419) 372-7716 (hsrb@bgsu.edu).

If you would like a copy of this consent form please let me know.

By completing this informed consent you are indicating your consent to participate in the study.

Print Name

Date

Signature

Date

BGSU HSRB - APPROVED FOR USE
ID #: 149746755E
EFFECTIVE: 10-30-06
EXPIRES: 10-21-07
APPENDIX D:

HEALTH HISTORY QUESTIONNAIRE
MEDICAL HISTORY QUESTIONNAIRE

All information given is personal and confidential. It will enable us to better understand you and your health and fitness habits. In addition, we will use this information to classify your health status according to the American College of Sport Medicine in ACSM's Guidelines for Exercise Testing and Prescription (2006). Please let us know if and when you have changed your medication (dose & type), diet, exercise or sleeping habits within the past 24 or 48 hours. It is very important for you to provide us with this information.

NAME_________________________________________AGE_________DATE________________

OCCUPATION_____________________________________

1. FAMILY HISTORY

Check each as it applies to a blood relative:

* Heart Attack  yes____no____unsure____
If yes, age at onset__________years

* Sudden Death yes____no____unsure____
If yes, relation to you__________
Age of relative at onset__________years

Tuberculosis yes____no____unsure____
Stroke yes____no____unsure____
Asthma yes____no____unsure____
High Blood Pressure yes____no____unsure____
Circulatory Disorder yes____no____unsure____
Heart Disease yes____no____unsure____

Father’s Age______Deceased________
Age at death________

Mother’s Age______Deceased________
Age at death________

2. PERSONAL HISTORY

Check each as it applies to you:

* Current Cigarette Smoking
  yes____no____unsure____

* High Blood Pressure
  yes____no____unsure____
  Systolic Blood Pressure ≥140mmHg
  or diastolic ≥90mmHg
  If yes, give value if known:_____/&____mmHg

* High Blood Cholesterol

* Current Alcohol Drinking
  yes____no____unsure____

* Current Medications
  yes____no____unsure____
  Total Serum Cholesterol >200 mg·dl⁻¹
  If yes, give value if known:_______mg·dl⁻¹

* Diabetes Mellitus
  yes____no____unsure____
  If yes, age of onset:__________years

* Obesity – BMI >30 kg·m⁻²
* Sedentary Lifestyle  
Yes____ No____ Unsure____  
Persons not participating in a regular exercise program or not meeting the minimal physical activity recommended from the U.S. Surgeon General’s Report.


Have you ever had:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Yes</th>
<th>No</th>
<th>Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allergy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuberculosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart Attack</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angina</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EKG Abnormalities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emphysema</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe Illness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospitalized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Outs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gout</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nervousness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joint Problems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Convulsions</td>
<td>Yes</td>
<td>No</td>
<td>Unsure</td>
</tr>
<tr>
<td>Paralysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headaches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest Pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm Pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shortness of Breath</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indigestion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulcers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overweight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hernia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back Pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Cramps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Blood Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insomnia</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For Office Use Only:

_____ Number of coronary heart disease risk factors* (according to Table 2-4 ACSM (2006))

*NOTE: All risk factors are explained verbally to each person completing the questionnaire. Classification according to ACSM (2006): ____ Low risk; ____ Moderate risk; ____ High risk

3. MEDICAL HISTORY

Name of your physician ________________________________

Date of your most recent physical examination ________________________________

What did the physical examination include? ________________________________

Have you ever had an exercise EKG? Yes____ No____

Are you presently taking any medications? Yes____ No____

List name and dosage ________________________________

(Include over-the-counter medications and/or herbs)
Have you ever taken:

Digitalis    yes____ no____ unsure____    Insulin yes____ no____ unsure____
Nitroglycerin yes____ no____ unsure____    Pronestyl yes____ no____ unsure____
High Blood Pressure yes____ no____ unsure____    Vasodilators yes____ no____ unsure____
Medication yes____ no____ unsure____    Other yes____ no____ unsure____
Sedatives yes____ no____ unsure____ If yes, list medications:______________________________
Inderal    yes____ no____ unsure____

4. EXERCISE HISTORY

Do you exercise? Yes____ No____ What activity________________________________________
How long have you been exercising?______________________________
How many days do you exercise?______________ How many minutes per day?________________
What kinds of shoes do you work out in?_______________________________________________
Where do you usually exercise?_______________________________________________________
Do you monitor your pulse during your workout?_________________________________________

5. HEALTH HISTORY

At Age    At Age    At Age    One Year    Most    Least Weighed    After
20    30    40    Ago    Weighed    Age 20

Height_____Weight_____

Do you use Health Foods? Yes____ No____ List___________________________________________
Do you take Vitamin pills? Yes____ No____ List__________________________________________
Approximate your daily intake: Coffee_____ Tea_____ Coke_____ Beer_____ Wine
Liquor_
Do you smoke or use tobacco products?  Yes____ No____

If yes, approximate your daily usage:  Cigarettes____  Cigars____  Pipes____  Chewing Tobacco____

Did you ever smoke?  Yes____ No____  How many years?____  Age when you quit____

Approximate the number of hours you work per week?____  Vacation weeks per year____

Home Status:  Very happy____  Pleasant____  Difficult____  Problem____

Work Status:  Very happy____  Pleasant____  Difficult____  Problem____

Do you feel you are stressed?  Yes____  No____  Unsure____

Are you worried about your health?  Yes____  No____  Unsure____

6. APPROXIMATE A TYPICAL 24 HOUR DAY FOR YOU

Number of hours:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td></td>
</tr>
<tr>
<td>TV</td>
<td></td>
</tr>
<tr>
<td>Relaxation/Leisure Activities</td>
<td></td>
</tr>
<tr>
<td>Driving/Riding</td>
<td></td>
</tr>
<tr>
<td>Eating</td>
<td></td>
</tr>
<tr>
<td>Exercise</td>
<td></td>
</tr>
<tr>
<td>Sleep</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>

Additional information from client interview to further assess health/coronary risk status:


Signature of Tester  Date
APPENDIX E:

AGE APPROPRIATE BODY FAT PERCENTAGE EQUATION
Age Appropriate Body Fat Percentage Equation

Men: $1.10938 - 0.0008267 \text{(sum of three skinfolds)} + 0.0000016 \text{(sum of three skinfolds)}^2 - 0.0002574 \text{(age)}$

Women: $1.099421 - 0.0009929 \text{(sum of three skinfolds)} + 0.0000023 \text{(sum of three skinfolds)}^2 - 0.0001392 \text{(age)}$

(Jackson & Pollack, 1985)
APPENDIX F:

CORRELATION MATRIX FOR MALE PARTICIPANTS
## Correlation Matrix for Male Participants

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<thead>
<tr>
<th></th>
<th>RMR</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
<th>BMI</th>
<th>Body Fat</th>
<th>Waist</th>
<th>Hip</th>
<th>Ratio</th>
<th>Abdominal Diameter</th>
<th>Daily Steps</th>
<th>PA Cals</th>
<th>PA Min.</th>
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</thead>
<tbody>
<tr>
<td>RMR</td>
<td>1.00</td>
<td>.537</td>
<td>.077</td>
<td>.629</td>
<td>.609</td>
<td>.750</td>
<td>.571</td>
<td>.552</td>
<td>.146</td>
<td>.805</td>
<td>-.483</td>
<td>.093</td>
<td>.167</td>
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<tr>
<td></td>
<td>(R²=.288</td>
<td>(p=.380)</td>
<td>(R²=.395)</td>
<td>(R²=.300)</td>
<td>(R²=.300)</td>
<td>(R²=.300)</td>
<td>(R²=.266)</td>
<td>(R²=.206)</td>
<td>(p=.004)</td>
<td>(R²=.648)</td>
<td>(R²=.233)</td>
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<td>(p=.417)</td>
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<td>(p=.315)</td>
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<td></td>
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APPENDIX G:

CORRELATION MATRIX FOR FEMALE PARTICIPANTS
## Correlation Matrix for Female Participants

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