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The Relationship Between Steps Walked Per Day and Body Composition in Postmenopausal Women

Emily Martin Krumm
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To the Graduate Council:

I am submitting herewith a thesis written by Emily Martin Krumm entitled "The Relationship Between Steps Walked Per Day and Body Composition in Postmenopausal Women." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Exercise Science.

Dixie L. Thompson, Major Professor

We have read this thesis and recommend its acceptance:

Edward T. Howley, David R. Bassett, Jr.

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Vice Chancellor and
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The relationship between steps walked per day and body composition in postmenopausal women

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Emily Martin Krumm

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ABSTRACT

The objective of this study was to examine the relationship between pedometer-determined physical activity measured in steps per day and body composition in healthy, postmenopausal women. Ninety-three women (60.9 ± 5.76 years) participated in the study. Subjects made one visit to the laboratory for height, weight, percent body fat, and waist and hip circumference measurements. Subsequently, each subject wore a pedometer for 14 consecutive days to assess average daily steps. Subjects recorded each day's accumulated step count and reset the pedometer the next morning. Pearson product moment correlations were used to examine the relationship between average steps per day and body composition variables. Partial correlation coefficients were calculated to determine if age influenced the relationship between steps and body composition variables. Subjects were placed in groups to reflect different levels of physical activity: sedentary (< 5,500 $steps \cdot d^{-1}$), low active (5,500-7,500 $steps \cdot d^{-1}$), and active (> 7,500 $steps \cdot d^{-1}$). ANOVA was used to determine whether body composition variables varied across activity groups. A $P < 0.05$ was considered significant for all tests. A significant correlation was found between average steps per day and percent body fat (r = -0.368 $P < 0.0001$); body mass index (BMI) (r = -0.422, $P < 0.0001$); waist circumference (r = -0.487, $P < 0.0001$); hip circumference (r = -0.435, $P < 0.0001$); and waist-to-hip ratio (r = -0.487, $P = 0.004$). These relationships remained significant after controlling for the influence of age. There was a significant difference in body composition

variables among activity groups, with higher values found in the less active groups.

In conclusion, this is the first study to investigate the relationship between average steps taken per day and body composition variables specifically in postmenopausal women. Although the cross-sectional nature of the study does not allow causal relationships to be determined, women who walked greater than 7,500 steps per day had more favorable body composition values. Additionally, the average BMI of the women in the active category (accumulating > 7,500 steps per day) was in the recommended range.

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CHAPTER 1

INTRODUCTION

Over the past few decades, overweight and obesity have been rising in epidemic proportions in many countries world-wide. Currently, in the United States, 64.5% of adults are overweight and 30.5% are obese (36). Many would agree that a combination of poor diet and decreased leisure and work-related physical activity have played a role in the increased incidence of overweight and obesity in this country. Unfortunately, the amount of physical activity necessary to prevent weight gain is not known. The joint statement published in 1995 by the Centers for Disease Control and Prevention and the American College of Sports Medicine recommends that every adult accumulate at least 30 minutes of moderate-intensity physical activity on most, preferably all, days of the week (87). However, the Institute of Medicine suggests that 30 minutes of activity per day may not be sufficient to maintain a healthy body weight in adults. Instead, they recommend 60 minutes of moderate-intensity physical activity daily to prevent weight gain and obtain maximal additional, weight-independent health benefits (120). Therefore, the scientific community has not yet determined the amount of exercise necessary for weight loss or weight maintenance.

Although obesity prevalence is increasing across all age groups, women are particularly susceptible to weight gain and increased body fatness in the years surrounding menopause (28). In fact, the prevalence of obesity in women increases significantly each decade, until it begins to taper off late in life (35). Although there is some debate as to whether weight gain in postmenopausal women is due to age or to menopause per se, menopausal women do demonstrate both increases in weight and total and central body fat around the time of menopause (7). In addition, postmenopausal women demonstrate a progressive decrease in lean mass and resting metabolic rate (5, 30). One reason cited for these deleterious changes in body composition is decreased physical activity (30).

A plethora of health consequences accompany increases in overweight and obesity including increased risk for cardiovascular disease, type 2 diabetes, hypertension, osteoarthritis, and health disorders (26, 114). Because physical inactivity is considered to be one of the most important factors in the increasing incidence of overweight and obesity, there is renewed interest in methods of assessing physical activity including objective monitoring of daily physical activity. A promising tool is the electronic pedometer. Pedometers are inexpensive, easy to use, and can provide immediate feedback on accumulated ambulatory physical activity. Researchers are beginning to define a relationship between pedometer-measured steps per day and indicators of body composition and other health consequences of physical activity (116, 123, 124).

It has been reported that maintaining physical activity levels throughout life helps maintain resting metabolic rate and more healthful body composition with age (43). Additionally, these changes in body composition are associated with an improved cardiovascular disease profile (111). A handful of studies have used pedometers to examine the relationship of steps walked per day and body composition in adult populations. In general, the studies report a more favorable body composition profile with higher levels of ambulatory activity (33, 38, 76, 121, 123, 125). Several of these investigations included both men and women (33, 76, 123, 125). Three studies focused on women of varying ages. However, none specified menopausal status (38, 116, 121). For the populations studied, there was a negative relationship between steps per day and BMI. However, because menopausal status is known to affect both activity level and body composition, it is unclear whether the previous trends will be evident in postmenopausal women. Therefore, establishing a clear relationship between physical activity measured in steps per day and body composition in postmenopausal women will help provide a basis for exercise prescription and further define the quantity of physical activity required for healthy body composition in this population.

Purpose

The purpose of this study was to investigate the relationship between ambulatory physical activity, measured in steps per day, and body composition in healthy, postmenopausal women.

Hypothesis

Postmenopausal women who take more steps per day will have lower BMI, lower % body fat, trunk fat, and lower waist and hip circumferences compared to those with lower current physical activity.

CHAPTER 2

REVIEW OF LITERATURE

The current life expectancy for women in the United States is 79.8 years (1). As women are living over one-third of their lives post-menopause, the importance of maintaining quality of life and independence after menopause is increasingly important. Although menopause is associated with unfavorable body composition changes such as increased body fatness that are related to chronic disease risk, lifestyle changes, including increased physical activity, can attenuate the undesirable effects of menopause (105, 106).

Menopausal Weight Gain

Menopausal women experience changes due to advancing age and changes attributed to menopause itself. Aging is associated with a decline in physical activity and resting energy expenditure (30). Most of the time, this decrease in energy expenditure is not accompanied by a similar decrease in energy intake (109). A positive energy balance and therefore weight gain and increased body fat results (109). Thus, aging is also associated with an increase in obesity (41). In 1998, nearly 2/3 of women 50-69 years of age were overweight or obese (35). Although many researchers attribute weight gain in postmenopausal women more to age than to menopause per se, menopause is associated with increases in total and central body fat (68, 86, 110, 115, 141). This change in body fat distribution is evident even in weight stable women. Postmenopausal women show progressive loss of lean tissue and increase in trunk fat (141). The clinical consequences of increased body fat include type 2 diabetes, hypertension, osteoarthritis, and coronary heart disease (CHD) (27, 117). Unfortunately, the added central fat to the trunkal area associated with menopause yields greater risk of CHD than increased body fat percentage alone (23-26).

Weight gain and increased body fatness associated with menopause may be more closely associated with behavioral and cultural changes that occur with aging rather than changing hormones (105). For example, decreased physical activity, which is associated with aging and menopause, leads to diminished fat-free mass and increased body fat observed with menopause (51). In fact, decreased physical activity has been shown to be positively correlated with increases body fat and waist circumference in aging women (7). Hence, regular exercise may diminish the increases in body fat associated with aging (62, 88). Habitual exercise can help maintain resting metabolic rate (RMR) and lower body fat levels in middle-aged women (43). Additionally, exercise helps prevent loss of fat-free mass, bone mineral density, strength, and functional ability that occur with aging (43). Several studies have shown that active postmenopausal women have less trunk and total fat than their sedentary counterparts (6, 43, 62, 118, 119, 132, 141). Furthermore, a review of cross-sectional and longitudinal studies revealed that postmenopausal women with high levels of physical activity have lower body fat and abdominal fat and are less likely to gain total and abdominal fat during menopause than women with low levels of physical activity (7).

Overall, the postmenopausal years are associated with unfavorable changes in several health variables. However, it has been shown that these unwanted changes may be partially prevented through lifestyle changes including increased physical activity. Although postmenopausal women experience greater increases in body fat and decreases in fat-free mass and leisure time physical activity than pre- or peri-menopausal women, it has been shown that the effects of physical activity are more profound in postmenopausal women compared to premenopausal women (47). In pre- and postmenopausal women alike, favorable body composition variables and chronic disease risk factors may be positively influenced with regular, moderate physical activity such as walking (12).

Walking

Walking is a natural activity that is common to almost everyone except for the seriously disabled (81). There is no need for equipment, special skills or facilities for walking. It is a convenient addition to both occupational and domestic routines. Furthermore, because intensity, duration, and frequency of walking are self-regulated, the activity is inherently safe (81). Walking offers year-round, self-reinforcing activity that is within the capability of most sedentary populations including the elderly.

Walking is one of the most popular forms of physical activity in the United States and is the most common form of exercise among women (21, 71). In addition, DiPietro et al. (28) report that walking was the only activity that increased in prevalence with increasing age among women (28).

Substantial health benefits can be achieved through regular walking including decreased cardiovascular disease risk, decreased risk of some forms of cancer, decreased blood pressure, decreased incidence of type 2 diabetes, and improved body composition (80, 81, 114). However, the benefit of walking versus vigorous exercise in the prevention of cardiovascular disease remains controversial. In the Women's Health Initiative Observational Study, over 70,000 postmenopausal women participated in a study comparing physical activity scores, walking, vigorous exercise, and hours spent sitting. Manson et al. (71) reported a higher physical activity score had a strong, graded, inverse relationship with the risk of cardiovascular disease. Furthermore, walking was associated with similar risk reduction compared to vigorous exercise. Women who walked or took part in vigorous exercise for at least 2.5 hours weekly had approximately a 30% decreased risk of cardiovascular disease. Although walking and vigorous exercise were both successful in decreasing cardiovascular disease risk, walking pace proved to be an important determinant of reduction of risk. Women who walked faster had greater decreases in risk with those walking 4.0 mph or faster having the greatest risk reduction. The decreased cardiovascular disease risk associated with both walking and vigorous exercise was evident regardless of race, age, and body mass index category (71).

Similar to the Women's Health Initiative Observational Study, several studies involving large subject populations including women have suggested that moderate exercise like walking has similar cardiovascular benefits to vigorous exercise (63, 66, 72). Moderate intensity exercise has been shown to yield similar or better reductions in blood pressure compared to vigorous exercise (131). In addition, moderate activity paired with diet modification has been shown to decrease the incidence of type 2 diabetes in people with impaired glucose tolerance (60, 130). Finally, physical activity of any intensity is associated with improved mental and emotional well-being (131).

The question of intensity is also an issue when considering the effects of physical activity on body composition. Some studies suggest that high levels of physical activity like vigorous endurance exercise are required to achieve body composition benefits (31, 61, 62, 111, 132, 142). However, other evidence suggests that moderate intensity exercise may lead to significant benefits to postmenopausal women. Tucker and Peterson (122) assessed physical activity with accelerometers in 278 middle-aged women. Percent body fat was estimated via Bod Pod and energy intake was assessed with 7-day diet records. The data showed a strong inverse association between intensity and duration of activity and body fat percentage when controlling for energy intake. Although the minimal effective dose has yet to be defined, several studies have shown that regular, moderate exercise can partially offset the increase in total and central body fat associated with menopause (40). In fact, Slentz et al. (107) reported that without a change in diet, a modest increase in physical activity like a daily 30-minute walk can compensate for the positive caloric imbalance associated with aging women (107). In addition, it has been reported that although moderate exercise like walking may not be sufficient to maximally increase physical fitness, it may decrease intra-abdominal fat and thereby reduce CVD risk in women (53). Furthermore, brisk walking has been shown to decrease body weight and total body fat in overweight and obese postmenopausal women (55). DiPietro (28) reported that walking was significantly associated with mean weight among people ages 40 and older. In fact, women aged 40-54 who walked regularly weighed about 6 pounds less than their counterparts who reported no physical activity (28). Whitt et al. (140) used accelerometers, pedometers, and physical activity records to assess physical activity in 55 African-American women ages 25-55. They showed that few participants met the current physical activity recommendations because activity was performed on too few days of the week and activity was not sustained for the recommended length of at least 8-10 minutes. However, women in the recommended BMI range accumulated more activity than those in the overweight or obese categories. Therefore, evidence suggests that meeting the current physical activity guidelines published by the Surgeon General, the American College of Sports Medicine and the Center for Disease Control of accumulating at least 30 minutes of moderate intensity exercise on most, preferably all, days of the week has been shown to incur improvements in body composition and overall CVD risk profile in postmenopausal women (131).

Other studies have utilized pedometers to investigate the relationship of steps walked daily to fitness and body composition. Ichihara et al. (54) used pedometers to quantify physical activity for one week in 513 middle-aged Japanese adults. Subjects were divided into fitness categories based on initial VO_2max measurements. Researchers found a significant positive association between steps walked per day and fitness levels. Subjects who walked more tended to have better cardiovascular fitness (54). A handful of studies have demonstrated a clear association between pedometer-measured ambulatory activity and body composition variables. Tryon et al. (121) investigated the relationship between pedometer-measured miles per hour and percent overweight in 127 women ages 19-55. Percentage of desirable weight was determined using the Metropolitan Life Insurance tables and miles per hour were determined by pedometer-measured distance and time the pedometer was worn. Participants wore pedometers for 14 consecutive days. Activity measured in miles per hour was shown to be inversely related to percent overweight ($r = -0.217$, $P < 0.05$) and BMI ($r = -0.194$, $P < 0.03$) in this population (121). In a similar study, Edelman et al. (33) reported a significant inverse relationship ($r = -0.26$, $P < 0.05$) between percentage overweight and steps walked per day in a mixed population aged 17-51 years. Other investigators have examined the relationship between steps accumulated per day and body mass index. Tudor-Locke et al. (123) investigated the relationship between pedometer-determined ambulatory activity and BMI and percentage body fat in 109 middle-aged men and women. The results indicate a significant inverse relationship between steps walked per day BMI (r = -0.30, $P < 0.01$) and percent body fat (r = -0.27, $P < 0.01$). In fact, subjects who walked greater than 9,000 steps per day were more frequently classified as normal weight compared to individuals who walked less than 5,000 steps per day who were more often classified as obese. Fogelholm et al. (38) reported a similar relationship (r = -0.44, P <0.05) between accumulated steps and BMI in overweight, middle-aged women. Thompson et al. (116) assessed the relationship between pedometer-measured physical activity and several body composition variables in eighty middle-aged women (50.3 ± 6.8 yr). A significant correlation was found between accumulated steps walked per day and percent body fat (r = -0.713, P <0.0001); body mass index (r = -0.417, P <0.0001); waist circumference (r = -0.616, P <0.0001); hip circumference (r = -0.278, P = 0.013); and waist-to-hip ratio (r = -0.652, P <0.0001). Women who walked more, had better body composition compared to those who accumulated less steps. Furthermore, the average body mass index of women who accumulated at least 10,000 steps per day was in the normal range.

Walking has also been shown to be a valuable part of weight loss and weight maintenance programs. In 2000, Fogelholm et al. (39) studied the effects of walking on 82 obese women. The women were placed on a very low calorie diet for 12 weeks and lost an average of 13.1 kg. Then, they were randomly assigned to one of three groups. One group received diet counseling and the other groups received counseling as well as a walking regimen of either 4.2 MJ / week or 8.2 MJ / week. The results showed that subjects in both walking groups regained less weight during the 40 week weight maintenance phase (39). In a study of healthy, sedentary, postmenopausal women, Asikainen et al. (6) reported that 24 weeks of moderate intensity walking (45% to 55% VO_2max) five days per week expended approximately 1000-1500 kilocalories and improved fitness and body composition. In another study of postmenopausal women, a walking program of 3 to 5 days per week at moderate intensity produced 1.1% to 1.3% decreases in percent body fat in a one-month period (91). Moreau et al. (80) reported an average 3 pound (1.3 kg) weight loss following 24 weeks of walking approximately 2 miles daily.

Because walking has been shown to confer significant health benefits, it is often recommended as a means of meeting current physical activity guidelines of 30 minutes of moderate intensity exercise on most, preferably all, days of the week (87). Additionally, the American Heart Association Task Force on Risk Reduction recommends walking as the best exercise for the secondary prevention of a heart attack (37).

Several factors make walking a viable option for postmenopausal women to improve their body composition. First, many women prefer walking over other forms of physical activity. Also, walking is a safe and convenient option for meeting physical activity recommendations. Finally, moderate physical activity such as walking has been shown to confer significant health benefits in postmenopausal women. For these reasons, walking provides an enjoyable method for postmenopausal women who want to improve or maintain body composition and health.

Body Composition Assessment

Body composition is an important part of postmenopausal women's health. It has been established that menopause is associated with a variety of changes in body composition including increased body fat at as well as decreased lean muscle tissue. Because these changes in body composition are associated with serious health consequences, the assessment of body composition is an important part of overall health appraisal in this population.

When considering body composition, it is common to divide all the body's tissues into two categories: fat mass and fat-free mass. A 2-compartment model may then be utilized to convert body density (sometimes measured via hydrostatic weighing or air displacement plethysmography) to percent body fat. One of the assumptions of this model is that the densities of fat and fat-free mass are 0.9 and 1.1 kg / L respectively (69). Although these numbers are considered relatively accurate for the general population, it is known that the density of fat-free mass can differ significantly for certain groups of individuals including postmenopausal women. As a result, more detailed models are often used for such populations. For these models, the fat-free component of the body is examined in more detail considering some of its individual parts: mineral, water, and protein. By using methods that may assess the individual parts of fat-free mass, a more accurate estimation of body fat percentage can be given. Because women lose a significant amount of bone in the years following menopause, total body mineral is an important variable when estimating body composition in this group. Lohman's 3-compartment model accounts for both total body mineral and total body density and will be used to calculate body fat percentage for this investigation.

It has been suggested that a significant part of the variability in fat-free mass is due to bone mineral which contributes approximately 13-19% to the density of fat-free mass (73, 78, 95). In addition, the coefficient of variation for bone mineral density in healthy subject ranges from 10-20% (73, 78). Because whole-body dual-energy x-ray absorptiometry (DXA) has been shown to accurately assess total bone mineral density, Lohman developed a 3-compartment model to account for variations in bone mineral. Lohman's 3-compartment model assumes the following densities: fat 0.9007 kg/L, mineral 3.037 kg/L, protein and water 1.0486 kg/L. The equation is as follows:

$$\%BF = (6.386/D_b + 3.961m - 6.09) \times 100$$

where D_b is body density (measured by air displacement plethysmography), and m is the total body mineral as a fraction of body weight. For this investigation, "m" will be calculated by multiplying the total bone mineral content in kg by a factor of 1.25 and subsequently dividing by the subject's body weight in kg as shown previously by Salamone et al. (95).

Bod Pod

Traditionally the "gold standard" for body composition assessment has been hydrostatic weighing (77). However, in the past decade, a new device has been marketed. The Bod Pod is an air displacement plethysmography device (22). The Bod Pod has been shown to be both reliable and valid in determining D_b and percent body fat in adults in comparison to hydrostatic weighing (77). In fact, same day test-retest reliability of the Bod Pod has been shown to be slightly better that hydrostatic weighing (133).

Dempster and Aitkens have described the physical design and operating procedures of the Bod Pod in detail (22). Briefly, the egg-shaped Bod Pod is constructed of fiberglass with a large acrylic window on its door. Inside, the subject sits on a molded seat that also serves to separate the instrument into two chambers. In the front chamber, measurements are taken while the rear chamber houses the instrumentation and serves as the reference chamber. The system determines the subject's body volume through air displacement. A volume perturbing diaphragm is mounted on the wall separating the two chambers of the Bod Pod. Through computer controlled oscillation, the diaphragm produces volume perturbations in the two chambers; this produces minute pressure fluctuations that are used to determine air volume in the chamber. The relationship between pressure and volume is described by Boyle's Law ($P_1 V_1 = P_2 V_2$). To assess a subject's body volume, there are two major steps involved. First, the air volume is determined while the chamber is empty. Then, the process is repeated with the subject inside the chamber. The subject's body volume is then simply calculated by subtracting the air volume with the subject inside the chamber from the air volume when the chamber is empty (133).

Using the Bod Pod to determine body volume and body density has several advantages over hydrostatic weighing. It is convenient, easy to administer, and yields rapid results. In addition, the Bod Pod method is less demanding for the subject compared to hydrostatic weighing. As a result, it is a practical method to use with older adults, physically challenged individuals, and those unwilling to be submerged in water. Unfortunately, the Bod Pod may not be able to accommodate the morbidly obese or those who may be claustrophobic due to its relatively small chamber size.

Dual Energy X-Ray Absorptiometry (DXA)

Another body composition assessment tool that has gained popularity over the last decade is dual energy x-ray absorptiometry. DXA uses an x-ray and a filter to produce two main energy peaks (75). The ratio of attenuation of these peaks differentiates fat from fat-free mass as the DXA scans a subject in the posterior to anterior direction (133). DXA whole body scans are performed with the subject lying supine on a padded table. During the scan, the x-ray passes through the bone and soft tissue upward to a detector. The measurement process takes approximately 20 minutes and exposes the subject to a minimal amount of radiation (the equivalent of approximately two hours of background radiation in the United States).

DXA has been shown to be both precise and accurate in assessing total body bone mineral and bone mineral density. Johnson and Dawson-Hughes (57) demonstrated the short- and long-term precision of DXA by scanning volunteers and then retesting each nine months later. The coefficients of variation for total body bone mineral and bone mineral density were 0.8 and 0.7 at the first measurement and 1.2 and 0.6 after nine months (57). The accuracy of DXA was assessed by Ho et al. (52). They measured bone mineral content and bone mineral density from 11 cadavers. The measurements given by DXA were highly correlated to the ash weight of the bone (r=.96, SEE=1.01g) (52). Thus, DXA has been shown to be both precise and accurate in measuring bone mineral content. DXA has also been shown to be valid in estimating trunk fat in adults. Snijder et al. (108) reported that total abdominal fat measured by DXA was strongly correlated with total abdominal fat assessed via CT (r = 0.98 for white women average age 74). The authors concluded that DXA was a good alternative to CT for predicting trunk fat in an elderly population. Svendsen et al. (113) compared the measurement of abdominal fat by DXA and CT in 25 postmenopausal women. Their results showed DXA to be valid for measuring trunkal fat (r = 0.9, s.e.e.%: 7%).

Anthropometric Measurements

Because centrally located excess fat is clearly associated with certain diseases, recent clinical guidelines have indicated that disease risk is best categorized by both body mass index (BMI) and waist circumference (83). Colombel et al. (20) report that the waist-to-hip ratio appears to be a useful indication of abdominal fat in group studies (20). Furthermore, studies investigating the relationship between waist circumference and abdominal fat measured compared to CT report that waist and hip circumference measurements can provide useful indication of abdominal fat (16, 19, 137). In a cohort of Swedish subjects over 50 years old, with an average follow-up of 12 years, there was a linear correlation between the incidence of coronary artery disease and waist-to-hip ratio (45). Thus, waist and hip circumference measurements have been shown to be useful in indicating central fat and its health risks. Additionally, body mass index (computed as weight in kilograms/ height in meters squared) has been shown to be correlated with abdominal fat (17). The calculation of body mass index is often used in disease risk stratification (4). Therefore, both waist and hip circumference measurements and BMI calculations will be used as indicators of body composition in this study.

Walking Assessment--Physical Activity Questionnaires

Due to the increasing prevalence of overweight and obesity in the United States, the CDC, ACSM, and U.S. Surgeon General have recommended that methods for measuring physical activity must be a high public health priority (87, 131). This is particularly important for at-risk populations such as postmenopausal women (74). Although there are numerous ways to estimate physical activity, questionnaires are used most frequently because they are simple to use (100). Furthermore, questionnaires are useful for large populations wherein traditional forms of activity measurement such as doubly labeled water and oxygen consumption would be too expensive (56, 64, 79). Numerous questionnaires have been created to assess physical activity. One of the most important factors in choosing a questionnaire is simply the time-frame for which they estimate energy expenditure. Questionnaires may assess one week to a lifetime of physical activity.

One popular questionnaire to assess physical activity is the Seven-Day Physical Activity Recall (PAR). It is a "general-purpose" measure of physical activity (96). It was originally developed by Blair in the 1980s (13), but has since been revised (46) and widely used in epidemiologic, clinical, and behavior change studies (96). The questionnaire may be used to estimate time spent in moderate, hard, and very hard intensity activity as well as the time spent sleeping for the seven days prior to the interview. The intensity of activities is estimated by the subject who is given established guidelines (13). For example, subjects are instructed to rate walking a moderate intensity while very hard would be similar to how one feels when running and hard would be somewhere in-between (96). In 2000, specific questions to assess strength and flexibility training were added to the interview (101). In order to be recorded, bouts of physical activity must be at least 10 minutes in duration (96). Standardized values of energy expenditure have been assigned to the various intensity levels (96). Standard MET values are then multiplied by hours recorded in each intensity category and an estimate of energy expenditure in kilocalories per week is calculated (96). The Seven-Day PAR has been shown to be both reliable (29, 46, 56, 90, 97-99) and valid (15, 29, 56, 82, 90, 97, 134) in a variety of populations including middle aged women (15, 56).

Another popular questionnaire used in assessing physical activity is the Paffenbarger Physical Activity Questionnaire. It covers average physical activity over the past year (84). Like the Seven-Day PAR, the Paffenbarger Physical Activity Questionnaire has been shown to be both reliable (2, 56, 65, 90, 135, 136) and valid (2, 3, 56, 65, 90, 104, 135, 136) in a variety of populations including postmenopausal women (65). The Paffenbarger Physical Activity Questionnaire assesses distance walked and stairs climbed each day as well as sport and recreational activities one has participated in during the past year. Like the PAR, the activities are each given a MET value and an estimate of total energy expenditure for an average week is computed (84).

Although both the Seven-Day PAR and the Paffenbarger Physical Activity Questionnaire are both widely used in large studies, they have some of the same flaws inherent in all questionnaires. For example, the standard MET values used with both questionnaires to convert reported activity into energy expenditure, metabolic costs are estimated based on data from young adults and tend to overestimate activity intensity in older people (48, 94). There are substantial differences both inter-individual and between individuals in energy cost of activity. Energy expenditure depends on age, sex, body mass, skill, and level of fatigue (32, 44, 85). In addition, when subjects are asked to rate their levels of intensity for questionnaires, their perception depends on the duration of activity as well as the age and fitness of the person (18). In addition to issues related to intensity, questionnaires also rely on the subject's ability to estimate distance (12). Also, a subject's report of her physical activity may also be influenced by the time of year. Both participation and frequency of certain activities vary dramatically with the seasons (103). Reporting may also be influenced by the perceived desirability of a certain response. For example, subjects tend to overestimate physical activity and underestimate sedentary behaviors (59). Obviously, both the Seven-Day PAR and the Paffenbarger Physical Activity Questionnaire fail to include all energy expenditure. For example, the PAR does not include any activity that is less than 10 minutes in duration or is less intense than walking. Multiple studies have shown that recall of moderate activity such as walking is less accurate than recall of structured, more vigorous exercise (8, 14, 92, 93, 98).

Although questionnaires provide valuable contextual information about physical activity, they rely on the recall ability of the subject, the interpretation of the interviewer and scorer, and the formulas derived to translate the recorded physical activity into energy expenditure (67). As a result, physical activity may be better approximated using a combination of measurement tools.

Walking Assessment--Pedometers

Some problems that are commonly associated with questionnaires can be attenuated with the addition of an objective tool for monitoring physical activity. Several objective tools like accelerometers and doubly-labeled water have been shown to be both reliable and valid for measuring physical activity in a free-living population. Unfortunately, cost is often prohibitive in using these techniques for large studies. For this reason, researchers are turning to pedometers for low-cost, objective monitoring tools (9, 42, 129, 138, 139).

Today's battery-operated digital pedometers detect vertical acceleration. Each up and down movement causes an internal spring-suspended lever arm to move up and down opening and closing an electric circuit. Each cycle is registered as a step, and the accumulated step count is shown on a digital display (123). Pedometers have been shown to correlate strongly with both observed activity and accelerometers (127). In fact, the DigiWalker pedometer has been shown to report within 3% of actual steps taken 95% of the time (102).

Because pedometers measure ambulatory activity, they are most sensitive to walking and running activities (128, 129). Although pedometers are unable to detect some forms of movement, walking is the most common activity contributing to overall daily energy expenditure and other forms of physical activity are intermittent (13, 74). In addition, pedometers capture both intentional as well as incidental walking throughout the day (11).

The idea of using pedometers to track daily activity is not new nor is the concept of accumulating 10,000 steps per day. In fact, it originated in Japan circa 1965. When pedometers went on the market, their name literally translated into "ten thousand steps meter" (50). Today the 10,000 steps per day recommendation is well known in Japan and is gaining popularity world-wide.

It is interesting to note that the 10,000 steps per day recommendation has some similarities to the current recommendation by the American College of Sports Medicine (ACSM) and the Center for Disease Control (CDC) to accumulate 30 minutes of moderate physical activity on most if not all days of the week (87). One study found that 73% of participants who performed at least 30 minutes of moderate activity also achieved at least 10,000 steps on the same day (139). Furthermore, it has been reported that the average adult gets approximately 6,000 to 7,000 steps daily excluding intentional exercise (11, 126). Welk (139) reports that the average 30 minute walk is about 3,800 to 4,000 steps. In one study, women who added a 30 minute walk increased average physical activity from 7,220 steps to 10,030 steps per day (139). Therefore, some evidence suggests that meeting the current ACSM and CDC physical activity recommendations may go hand in hand with meeting the popular 10,000 steps per day recommendation.

Several researchers have reported that accumulating 10,000 steps per day is associated with a myriad of health benefits including decreased body fat (50, 116, 123), decreased blood pressure (50, 80), improved glucose tolerance (114), and improved lipid profile (112). Another study showed steps per day to be inversely related to percent overweight in women aged 19-55 (121). In addition to direct health benefits resulting from walking 10,000 steps per day and meeting the current physical activity recommendations, some researchers have suggested that because pedometers offer immediate feedback, they may be used as behavior modification tools to help motivate people to exercise (12).

Because body composition has been shown to be a central issue when considering the overall health of postmenopausal women, it is important to investigate ways that this population may control body weight as well as improve general health. One documented way to improve body composition is through moderate physical activity such as walking. As a result, pedometers are a logical choice to simply quantify physical activity in an effort to establish specific guidelines relating physical activity and body composition variables in postmenopausal women.

CHAPTER 3

MANUSCRIPT

Abstract

Purpose: The purpose of this study was to examine the relationship between pedometer-determined physical activity measured in steps per day and body composition variables in healthy, postmenopausal women.

Methods: Height, weight, percent body fat, waist circumference and hip circumference were measured on ninety-three women (60.9 ± 5.76 years). Each subject wore a pedometer for 14 consecutive days following testing to assess average daily steps. Subjects recorded each day's accumulated step count and reset the pedometer the next morning. Pearson product moment correlations were used to examine the relationship between average steps per day and body composition variables. Partial correlation coefficients were calculated to determine if age influenced the relationship between steps and body composition variables. Subjects were placed in groups to reflect different levels of physical activity: sedentary (< 5,500 $steps \cdot d^{-1}$), low active (5,500-7,500 $steps \cdot d^{-1}$), and active (> 7,500 $steps \cdot d^{-1}$). ANOVA was used to determine whether body composition variables varied across activity groups. A $P < 0.05$ was considered significant for all tests.

Results: A significant correlation was found between average steps per day and percent body fat (r = -0.368, *P* < 0.0001); body mass index (BMI) (r = -0.422, *P* < 0.0001); trunk fat (r = -0.0.393, *P* < 0.0001); waist circumference (r = -0.487, *P* < 0.0001); hip circumference (r = -0.435, *P* < 0.0001); and waist-to-hip ratio (r = -0.487, *P* = 0.004). These relationships remained significant after controlling for the influence of age. There was a significant difference in body composition variables among activity groups, with higher values found in the less active groups.

Conclusions: This is the first study to investigate the relationship between average steps taken per day and body composition variables specifically in postmenopausal women. Although the cross-sectional nature of the study does not allow causal relationships to be determined, women who walked more had better body composition. Additionally, the average BMI of the women in the active category (accumulating and average of 9961 ± 309 steps per day) was in the recommended range.

Key Words: MENOPAUSE, PEDOMETER, BODY FAT, BMI, EXERCISE, AMBULATION

Introduction

In the years surrounding menopause, most women experience increases in both body weight as well as total and central body fat (68, 86, 109, 110, 115). The additional total and central fat has been linked to several chronic diseases including type 2 diabetes, hypertension, osteoarthritis and coronary heart disease (27, 117). However, moderate physical activity has been shown to offer some protective benefit from these hypokinetic diseases (43). The current physical activity recommendations encourage all adults to accumulate at least 30 minutes of moderate physical activity on most, preferably all days of the week (87). Studies have shown that by meeting the current physical activity guidelines, healthy, postmenopausal women have experienced improvements in body composition (6, 91) and decreases cardiovascular disease risk (63, 66, 71, 72). Because moderate exercise such as walking has been shown to confer significant health benefits, it is often recommended as a means of meeting current physical activity guidelines. Walking has been shown to reduce blood pressure (80, 131) as well as improve glucose tolerance (114). Walking is self-regulated in intensity, duration, and frequency. Therefore, it is inherently safe for most populations including those who are sedentary and older.

Questionnaires are vital tools for physical activity assessment especially for large groups. Various questionnaires have been shown to be both reliable and valid for estimating physical activity. However, they are limited by the recall ability of the subject, the interpretation of the interviewer or scorer, and the formulas used to translate the responses into energy expenditure (67). Therefore, the use of an objective monitoring tool provides important information in the quest to assess physical activity. Pedometers are becoming increasingly popular low-cost, objective monitoring tools.

Bassett et al. (10) demonstrated pedometers to be reliable in reporting number of steps walked per day. Pedometers record steps taken as a horizontal lever moves up and down opening and closing an electric circuit with ambulation. Each cycle is registered as a step, and the accumulated step count is shown on a digital display (127). Because pedometers are accurate for measuring steps taken, and walking is the most common form of exercise among women, it follows that pedometers may serve as valuable tools for measuring physical activity in this population.

Recently, researchers have begun to investigate the relationship between pedometer-determined ambulatory activity and body composition variables. In general, daily walking is inversely related to body mass index (38, 76, 116, 121, 123, 125), body fat percentage (116, 123), percent overweight (33, 121), and waist and hip circumference (116). Frequently, these studies have included wide age ranges of adults in their analyses. As a result, it is impossible to determine the potential effects of age on the body composition variables measured. In addition the majority of these studies included both men and women in body composition analysis which may also complicate analysis of the relationship between steps and body composition (33, 76, 123, 125). However, some studies focused specifically on women (38, 116, 121). Thompson et al. (116) examined the relationship between pedometer-determined ambulatory activity and body composition in middle-aged women (116). The results of this study showed a significant inverse correlation between pedometer-measured steps per day and BMI, percent body fat, and waist and hip circumferences. Furthermore, the mean BMI of women who accumulated at least 10,000 steps per day was in the recommended range (116). It is encouraging to note that the expected relationship between higher activity and better body composition is evident in a population of middle-aged females. However, previous investigations that included middle-aged women have not specified menopausal status. Because menopausal status is known to affect body composition, this study will utilize a 3-compartment model to more accurately estimate body fat percentage and will use DXA to estimate central fat. Because menopausal status is known to affect both activity level and body composition, it is unclear whether the previous trends will be evident in postmenopausal women.

The purpose of this study was to examine the relationship between pedometer-determined ambulatory activity measured in steps per day and body composition variables in healthy, postmenopausal women. By investigating a narrow age range and specifying postmenopausal status, we hope to delineate a clear relationship between accumulated daily steps and body composition. We hypothesized that postmenopausal women who take more steps per day will have lower BMI, lower body fat percentage, and less centrally located fat compared to those with lower current physical activity.

Methods

Subjects and General Protocol

Ninety-three Caucasian, healthy, postmenopausal women ages 50-75 volunteered for the study. Prior to participation, the nature, purpose, and risks of the study were explained to each subject and written consent (see Appendix A) was obtained. The experimental protocol was approved by the University of Tennessee Institutional Review Board. Subject qualifications included non-smoking, aged 50-75, absence of ambulatory limitations, and postmenopausal status determined by at least a two year absence of menses. Individuals who were currently taking or had taken hormone replacement therapy or any prescription medication for bone density improvements in the last 2 years were excluded from the study. Those with major joint (i.e., hip, knee, or shoulder) replacements, history of bone disease, or those who weighed more than 300 pounds were also excluded from the study.

Each subject came to the lab for a single testing session. At this time, height, weight, anthropometric measurements, body composition, and bone density tests were performed. All tests were conducted with the subject wearing a lycra, form-fitting swimsuit. After the laboratory visit, each subject wore a pedometer for 14 days to assess current physical activity levels. Also, each subject completed a 3-day dietary record. After these records were completed, the pedometer and food logs were mailed back to the laboratory in an envelope that was provided on the day of testing.

Anthropometric Measurements

Height was measured to the nearest 0.001m without shoes using a wall-mounted stadiometer (Creative Health Products, Inc., Plymouth, MI). Body mass was measured using the Bod Pod scale (Life Measurement Instruments, Concord, CA). Body mass index (BMI) was computed as mass in kg divided by height in meters squared.

Waist circumference (WC) and hip circumference (HC) measurements were made in duplicate to the nearest 0.1 cm using a Gulick fiberglass measuring tape with a tension handle (Creative Health Product, Inc., Plymouth, MI), and mean values were used in calculations. Waist measurements were taken at the narrowest portion of the torso between the rib cage and the iliac crest, after a normal expiration. Hip circumference measurements were taken at the greatest gluteal protuberance while the subject stood with the feet together.

Body Composition Testing

Body density (D_b) was estimated from air displacement plethysmography using the Bod Pod (Life Measurement Instruments, Concord, CA). Prior to each test, the Bod Pod was calibrated with known volumes of 0 and 49.774L. In order to minimize the effect of clothing and hair on measurements, all subjects were tested wearing lycra swimsuits and swim caps. After being weighed on the manufacturer's scale, each subject entered the Bod Pod chamber for two measurements of body volume. Each measurement lasted approximately 45 seconds. The average measurement was recorded if the two volumes were within 150 mL of each other. If the two measurements were different, a third trial was completed. If two similar measurements were not reported, the Bod Pod was recalibrated and the testing process repeated. Body volume was corrected for thoracic gas volume, which was estimated based on gender, age, and body size. Finally, body density was calculated from measured body volume and mass.

Total bone mineral content (BMC) was determined via whole-body scans using a Lunar DPX-NT whole-body x-ray densitometer (GE Medical, Milwaukee, WI), with software version 4.0. In addition, trunkal fat, defined as fat not on the extremities or head, was determined from this scan.

Due to bone loss, the density of fat-free mass can differ significantly in postmenopausal women. As a result, it is important to consider total body mineral in body composition assessment in this population. In this study, Lohman's 3-compartment model (70) was used to estimate body fat percentage from D_b and total body mineral according to the following equation: Body Fat Percentage= $(6.386/ D_b + 3.961m - 6.09) \times 100$. For the calculation, D_b is total body density from the Bod Pod and m is the fraction of body mass accounted for by total body mineral. Total body mineral as a fraction of total body weight was calculated using the total bone mineral content given in kg via DXA multiplied by 1.25 and divided by the subject's body mass in kg (95).

Measurement of Daily Steps

The subjects were instructed to wear a pedometer (Digi-Walker SW-200, New Lifestyles Inc., Lees Summit, MD) and record the number of steps taken daily for 14 consecutive days. Each subject was instructed on placement of her pedometer and given detailed instructions to wear the device during waking hours except when bathing or swimming. Subjects recorded steps per day along with a brief description of daily activity as well as the time the pedometer was put on and time it was taken off in a step log each night before going to bed. Subjects were encouraged not to alter their usual physical activity habits during the course of the test period. At the end of the study, subjects returned the pedometers and the step logs to the laboratory.

Dietary Record

Daily energy intake was estimated from 3-day food logs (2 weekdays and 1 weekend day) as described previously (58). Subjects were given detailed instructions for completing the dietary record and were encouraged not to alter their usual diet during testing. In order to improve accuracy of data analysis, subjects were encouraged to submit recipes and food labels with diet records in addition to providing specific brand names of foods and restaurants where meals were consumed. The dietary records were analyzed for total caloric intake and percentage of calories from each macronutrient using NutritionistPro software (Version 1.3, First DataBank, San Bruno, California).

Statistical Analyses

Pearson product moment correlations were used to examine the relationship between average steps per day and body composition variables. Partial correlation coefficients were calculated between steps per day and body composition variables while controlling for age. Subjects were placed in groups to reflect different levels of physical activity: sedentary (< 5,500 steps·d^{-1}), low active (5,500-7,500 steps·d^{-1}), and active (> 7,500 steps·d^{-1}). A $P < 0.05$ was considered significant for all tests. ANOVA was used to determine whether body composition variables varied across activity groups. All statistical analyses were performed using SPSS for Windows version 10.1 (SPSS, Inc., Chicago, IL).

Results

The subject characteristics are listed in Table 1. Both activity levels measured in steps per day and body composition variables varied widely among subjects. There was a significant negative correlation between average steps per day and BMI ($r = -0.422$, $P < 0.0001$); body fat % ($r = -0.368$, $P < 0.0001$); waist circumference ($r = -0.487$, $P < 0.0001$); hip circumference ($r = -0.435$ $P < 0.0001$); waist-to-hip ratio ($r = -0.296$, $P = 0.004$); and trunk fat ($r = -0.393$, $P < 0.0001$) (Table 2). There was also a

Table 1: Descriptive statistics (N=93)

Variable	Mean	SE	Minimum	Maximum
Age (yr)	60.9	0.6	50	75.9
Height (m)	1.645	0.006	1.501	1.781
Weight (kg)	75.1	1.8	45.3	134.8
BMI ($kg \cdot m^{-2}$)	27.7	0.6	17.1	49.5
Waist (cm)	89.2	1.4	62.2	134.9
Hip (cm)	106.5	1.3	82.4	147.7
WHR	0.84	0.01	0.69	1.23
Body fat (%)	40.2	1.0	15.9	56.5
$Steps \cdot day^{-1}$	6813	306	1292	14048

BMI, body mass index; Waist, waist circumference; Hip, hip circumference; WHR, waist-to-hip ratio; Body fat, body fat percentage; $Steps \cdot day^{-1}$, average steps accumulated per day.

Table 2: Pearson correlations and partial correlations (controlling for age) between average steps per day and body composition variables (N=93)

Variable	**Correlation**	***P***	**Partial Correlation**	***P***
BMI	-0.422	<0.0001	-0.513	<0.0001
Body fat (%)	-0.368	<0.0001	-0.378	<0.0001
Waist	-0.487	<0.0001	-0.504	<0.0001
Hip	-0.435	<0.0001	-0.529	<0.0001
WHR	-0.296	0.004	-0.217	0.037
Trunk fat (kg)	-0.393	<0.0001	-0.442	<0.0001

BMI, body mass index; Body fat, body fat percentage; Waist, waist circumference; Hip, hip circumference; WHR, waist-to-hip ratio, Trunk fat, kg of fat on the trunk.

significant negative correlation between average steps per day and age (r = -0.340, $P = 0.001$). However, there was no significant association between age and BMI, % body fat, waist circumference or hip circumference (r values ranging from r = -0.171, $P = 0.098$ to r = 0.042, $P = 0.687$). There was a significant positive association demonstrated, however, between age and waist-to-hip ratio (r = 0.297, $P = 0.004$). When partial correlations were used to account for the effect of age on the relationship between steps per day and body composition variables, all relationships remained significant (Table 2).

Comparison across activity groups shows a significant difference in the % body fat and BMI between the most active group (>7,500 average steps per day) and the less active groups. For each body composition variable, the lowest activity group had the highest % body fat, BMI, and circumference measurements while the most active group demonstrated significantly lower values (Table 3).

Kilocalories consumed ranged from 768 to 3848 kilocalories per day with an average of 1851 kilocalories. Pearson product moment correlations revealed no significant correlation between average kilocalories consumed and average steps accumulated (r = 0.020, $P = 0.850$). In addition, there was no correlation between reported kilocalories consumed and any of the body composition variables.

Table 3: Comparison of body composition variables across activity groups

	SEDENTARY < 5,500 (N=30)	LOW ACTIVE 5,500-7,500 (N=30)	ACTIVE >7,500 (N=33)
Mean steps	3622 ± 258 [a]	6541 ±108 [b]	9961 ± 309 [c]
BMI	30.5 (1.2)[a]	28.2 (1.0)[a]	24.6 (0.6)[b]
Body fat (%)	43.5 (1.5)[a]	41.6 (1.8)[a]	36.0 (1.5)[b]
Waist (cm)	98.3 (2.9)[a]	88.2 (1.8)[b]	81.8 (1.5)[b]
Hip (cm)	112.5 (2.6)[a]	107.5 (2.1)[a]	100.3 (1.2)[b]
WHR	0.87 (0.02)[a]	0.82 (0.01)[b]	0.81 (0.01)[b]
Trunk fat (kg)	18.5 (1.01)[a]	16.6 (0.92)[a]	13.3 (0.74)[b]

Values represent means and standard errors [mean (SE)].
Means with different letter superscripts are significantly different, $P < 0.05$.
BMI, body mass index; Body fat, body fat percentage; Waist, waist circumference; Hip, hip circumference; WHR, waist-to-hip ratio, Trunk fat, kg of fat on the trunk.

Discussion

This is the first study to investigate the relationship between pedometer-measured steps taken per day and body composition variables in postmenopausal women. Because of the myriad of physiological changes associated with menopause including decreased activity and increased total and central body fat, the relationship between steps per day and body composition variables in this population was uncertain. As has been reported in other groups, there were significant inverse relationships between steps per day and all body composition variables. Women who accumulated more steps per day had more favorable body composition including % body fat, trunkal fat, BMI, waist and hip circumferences, and waist-to-hip ratio. Subjects in the most active category, walking >7,500 steps daily (averaging 9961 ± 309 steps), had significantly lower body mass indices compared to the less active groups (Figure 1). Furthermore, the BMI of this group fell into the recommended healthy range (4, 34). Similarly, subjects in the most active category had lower total body fat percentages and less central body fat as measured by waist and hip circumference measurements and DXA (Table 3).

Walking is the most common form of physical activity reported by postmenopausal women (21, 28, 71). As a result, pedometer-determined activity may be particularly useful in quantifying activity in this group. However, in order to use pedometers in general exercise prescription, practical guidelines including step indices associated with health outcomes

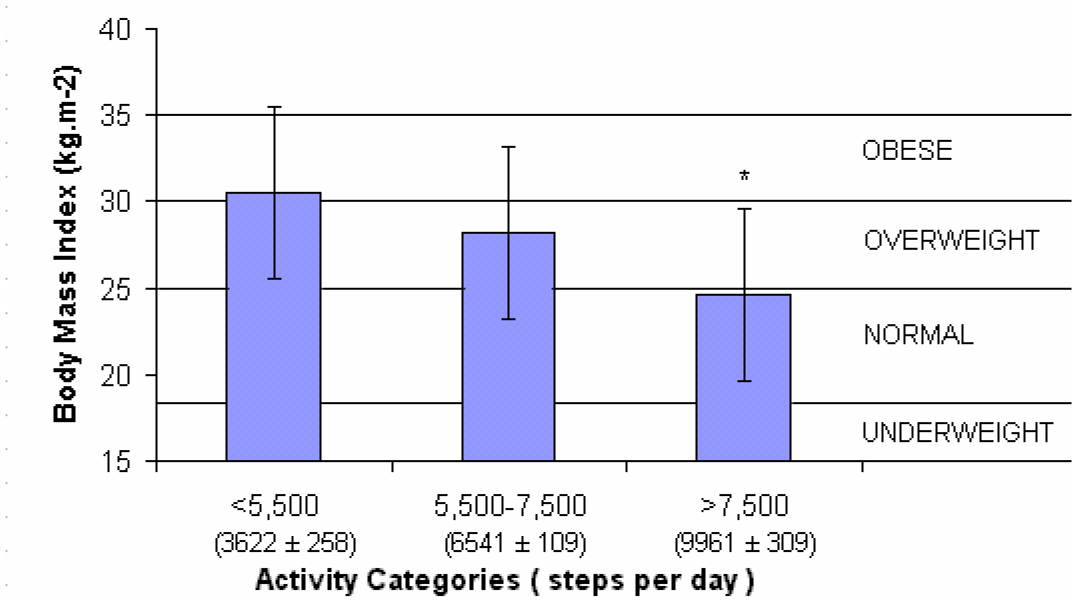

Figure 1—Body mass index of the activity groups; * significantly different (*P* < 0.03) from the groups averaging less than 7,500 steps·d^{-1}. Average steps per day ± SE for each category are given.

are needed. In an effort to establish such preliminary indices, Tudor-Locke and Bassett extensively reviewed existing pedometer studies. They suggest that <5,000 steps per day may be used to indicate a sedentary lifestyle for apparently healthy adults. Furthermore, 5,000-7,499 steps per day is considered "low active", 7,500-9,999 steps per day is "somewhat active", and greater than 10,000 steps per day would classify individuals as "active" (124). In the current study, similar activity categories were used. In agreement with the literature, subjects who walked less than 5,500 steps per day had poorer body composition than their more active counterparts. In fact, in higher activity levels, body composition was dramatically better. Thus, the data from this study lend support to current proposed pedometer indices for public health.

It is interesting to compare the results of the present study to the recent study by Thompson et al. (116). The subject population in that study included eighty women with an average age of 50 years. Menopausal status was not specified. Similar to the present study, body composition variables were inversely related to average steps walked per day. One striking difference was noted upon comparing average daily steps in the two subject populations. In the present study, the average subject age was 60.9 and all were postmenopausal. The average steps walked per day was 6813 ± 306 compared to 8354 ± 363 steps per day in the Thompson et al. study. In the most active groups, the average number of steps walked in the current study was 9961 ± 309 compared to 12,109 ± 305 in the Thompson et al. study (personal communication from Dr. Dixie Thompson). Because the current study population is both ten years older and postmenopausal, the decrease in average physical activity concurs with the literature (30). It is interesting to note, however, that although the older, postmenopausal subject population is less active compared with women ten years their junior, a significant inverse relationship is still evident between average steps walked per day and body composition variables. Furthermore, the average BMI in the most active category was in the normal range despite the approximate 2,148 step difference between the older and younger study populations.

Regular walking is associated with numerous health benefits including decreased cardiovascular risk and more healthful body composition (80, 81). In fact, DiPietro (28) reported that walking was inversely associated with mean weight among middle-aged adults. Women, aged 40-54, who walked regularly weighed about 6 pounds less than their counterparts who reported no physical activity (28). Several studies have shown that regular walking that meets current physical activity recommendations of 30 minutes of moderate intensity exercise on most days of the week confers significant improvements in body composition. In a study of healthy, sedentary, postmenopausal women, Asikainen et al. reported that 24 weeks of moderate intensity walking (45% to 55% VO_2max) five days per week that expended approximately 1000-1500 kilocalories weekly and improved fitness and body composition. In another study of postmenopausal women, a walking program of 3 to 5 days per week at moderate intensity produced 1.1% to 1.3% decreases in percent body fat in a one-month period (91). Moreau et al. (80) reported an average 3 pound weight loss following 24 weeks of walking approximately 2 miles daily. Furthermore, although the years surrounding menopause are associated with a general worsening of the cardiovascular risk profile, evidence suggests the benefits of physical activity are more profound in postmenopausal women compared to premenopausal women (47). Therefore, walking should be considered as one of the best methods for meeting moderate physical activity guidelines because of its proven benefits for cardiovascular health and body composition in women.

The present study has several limitations. First, the cross-sectional nature of the study limits conclusions about causation. Furthermore, the subjects were not selected randomly from the population. Instead, they were a convenience sample recruited through newspaper ads, flyers, and "word of mouth". However, the wide variation in steps walked per day and body composition variables is indicative of a diverse sample. Because this study investigated the relationship between steps walked per day and body composition variables in healthy, postmenopausal, Caucasian women, the results cannot be generalized to draw conclusions regarding men, women of different ages, or across races. Large-scale studies in more diverse populations will be required to fully investigate these relationships.

There were several important advances in this study. First, the estimate of percent body fat was made more precise by using Lohman's 3-compartment model (70). By using this model, we were able to account for variation in total body mineral due to bone loss in postmenopausal women. Additionally, this is the first study investigating the relationship between daily steps and body composition that included measurement of trunk fat via DXA whole-body scans as well as circumference measurements. As discussed previously, trunk fat is an important indicator of disease risk. Furthermore, this investigation focused on a narrow age ranged population and statistically controlled for the effect of age on average daily steps. It is clear that in this group of women the relationship between ambulatory physical activity and body composition is real and not an artificial influence of age on body composition. These unique features of this study gave additional insight to the relationship between average daily steps and body composition in postmenopausal women.

Conclusion

The findings of this study indicate a clear inverse association between accumulated daily steps and body composition variables in healthy, postmenopausal women. The subjects in the most active group (averaging 9961 ± 309 steps per day) had a BMI in the recommended range and a significantly lower percent body fat and central fat compared to less active women. This suggests that increasing physical activity to accumulate approximately 10,000 steps per day regularly may be an effective means for attenuating increases in body fat in the postmenopausal years.

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APPENDICES

APPENDIX A

INFORMED CONSENT

INFORMED CONSENT

Title of Study: Relationship between Measured Physical Activity and Health Risk Factors Healthy Postmenopausal Women

Investigator:	Dr. Dixie Thompson
Student Investigators:	Olivera Lukajic and Emily Krumm
Address:	The University of Tennessee Department of Health and Exercise Science 340 Health, Physical Ed. & Rec. 1914 Andy Holt Ave. Knoxville, TN 37996
Telephone:	(865) 974-5091

PURPOSE

You are invited to participate in a research study examining the relationship between physical activity and health risk factors in healthy postmenopausal women. Testing will take place at the University of Tennessee Applied Physiology Laboratory in the Health, Physical Education, and Recreation Building. This testing will take approximately 1.5 hours. Following the testing you will wear a step counter (pedometer) for 14 days and also record all that you eat and drink for 3 days. You will also make 1 visit to the UT Medical Center for blood withdrawal.

PROCEDURES

1. Your blood pressure will be measured by placing a cuff around your upper right arm. This cuff will be inflated with air and then slowly deflated. By listening to the sound of the pulse in your arm, it is possible to determine your blood pressure.
2. You will complete some surveys. These surveys will ask information about your past history of physical activity, your health status, and your current physical activity.
3. We will measure your height, weight, and distance around your hips and waist.
4. Bone mineral density will be measured by dual-energy X-ray absorptiometry (DXA). This is a common method for assessing bone mineral density and is the test used by doctors to test for osteoporosis. During this test, you will lie on your back for about 15-20 minutes while the measurements are being made.
5. Your body fat percentage will be determined by the use of the Bod Pod®. The Bod Pod® is a device that measures your body fat as you sit inside it for approximately 3 minutes. Because clothing interferes with the test results, you will wear a bathing suit or your undergarments for this procedure. You can see your surrounding and breathe normally during this test.
6. You will be given an electronic pedometer to wear for 14 consecutive days. You will be asked to record the number of steps you take each day and also provide a brief description of your daily activity (e.g. walking, gardening, etc). You will also be responsible for keeping a three-day dietary log in which you will write down all food and drinks that you consume for 3 days.
7. You will make 1 trip to the UT Medical Center for a blood test. Approximately 2 teaspoons of blood will be withdrawn from an arm vein to measure variables related to risk of heart disease.

RISKS ASSOCIATED WITH PARTICIPATION

There are very few risks associated with this study. You are asked not to change your normal routine, so any exercise performed is reflective of your typical activity. There are no known risks to body composition measurements. There is a small amount of radiation exposure from the DXA. However, the radiation is equivalent to about 2 hours of sun exposure. The risks of blood withdrawal include localized bruising and soreness as well as a small possibility of infection. These risks will be reduced by having a trained technician conduct all blood withdrawals following professionally approved techniques.

BENEFITS ASSOCIATED WITH PARTICIPATION

You will receive the results of your bone mineral density scan, blood pressure measurement, blood tests, and body composition tests. You may share this information with your primary physician for interpretation and diagnosis. You will also benefit by obtaining valuable information on your current physical activity levels and gain knowledge on some health benefits of exercise. You will also learn your total caloric intake per day, how many calories are coming from carbohydrates, fats, and proteins. You will also know what your calcium and iron intake are along with other vitamins and minerals.

CONFIDENTIALITY

The information from this study will be treated as privileged and confidential and will consequently not be released to any person without your consent. All information collected will be coded by subject numbers rather than names. The data will be kept in a locked cabinet in 317 HPER. However, the information will be used in research reports and presentations, but your name and other identity will not be disclosed.

QUESTIONS

If you have any questions or concerns at any time during this study or after you have completed this study, you may contact Dr. Thompson at (865) 974-8883; Olivera Lukajic at (865) 974-5091; or Emily Krumm at (865) 974-4215. During this study if any events occur that will keep you from completing your participation in this study you should inform Olivera, Emily, or Dr. Thompson immediately. You are free to decide whether or not to participate in this study and are free to withdraw at any time. Before you sign this form, please ask questions regarding any aspect of the study which is unclear to you. You may also contact Research Compliance Services of the Office of Research at (865) 974-3466 if you have any questions about your rights as a participant.

CONSENT

By signing this paper, I am demonstrating that I have read and understand this document, and that I agree to take part in this research study.

____ ____________

Your signature Date

____ ____________

Researcher's signature Date

APPENDIX B

HEALTH ASSESSMENT QUESTIONNAIRE

HEALTH HISTORY QUESTIONNAIRE

1. Have you ever been diagnosed with any of the following conditions? Please check the appropriate column.

____Asthma	____Gout	____Osteoarthritis
____Back Pain	____Heart Problems	____Osteoporosis
____Bronchitis	____High Blood Pressure	____Rheumatoid Arthritis
____Cancer	____High Cholesterol	____Stroke
____Diabetes	____Hypoglycemia	____Thyroid Problem
____Emphysema	____Kidney Problems	____Metal in the Body
____Epilepsy	____Liver Problems	

2. Do you have any other physical conditions that may limit your ability to be physically active? If so, please describe:

____

____

3. Are you currently taking any medications? Yes No

If yes, please list.

____

____

4. Do you currently smoke or have you quit within the last 6 months? Yes No

If yes, what type of tobacco products and how many per day?

____

____

5. Are you currently taking hormone replacement therapy? Yes No

Have you ever been on hormone replacement therapy? Yes No

If yes, when did you stop? ___________years

and how long did you take it? ________years

6. Of the following members of your family, please describe any cardiovascular disease, heart disease, stroke, or diabetes, along with the age of onset.

Father____

Mother____

Brother____

Sister____

APPENDIX C

PHYSICAL ACTIVITY QUESTIONNAIRES

PHYSICAL ACTIVITY QUESTIONNAIRES

Each subject completed Paffenbarger and Seven-day physical activity questionnaires to assess recent physical activity (84, 96). The questionnaires were collected immediately prior to a 14-day pedometer measurement of ambulatory physical activity. Pearson product moment correlations were used to examine the relationship between pedometer-assessed activity and questionnaire-assessed activity. The Paffenbarger physical activity questionnaire estimate of kilocalories utilized per week was positively correlated with pedometer measured steps per day ($r = 0.397$, $P < 0.0001$). However, the kilocalories expended per week estimated from the Seven-day PAR revealed no significant correlation with pedometer-measured ambulatory physical activity. This is in agreement with findings from middle-aged Caucasian women (personal communication from Dr. Dixie Thompson).

Paffenbarger Physical Activity Questionnaire

1. How many city blocks or their equivalents do you normally walk each day?
   ______ blocks/ day (Let 12 blocks = 1 mile.)

2. What is your usual pace of walking? (Please check one.)
   a. _____ Casual or strolling (less than 2 mph)
   b. _____Average or normal (2 to 3 mph)
   c. _____Fairly brisk (3 to 4 mph)
   d. _____Brisk or striding (4 mph or faster)

3. How many flights of stairs do you climb <u>up</u> each <u>day</u>?
   ______ flights / day (Let 1 flight = 10 steps)

4. List any sports or recreation you have actively participated in during the past <u>year</u>. Please remember seasonal sports or events.

Sports, recreation, or other physical activity	Number of times/ year	Average Hours	time/ episode Minutes	Years participation
a.				
b.				
c.				
d.				
e.				
f.				

5. Which of these statements best express your view? (Please check one.)
   a. _____I take enough exercise to keep healthy.
   b. _____I ought to take more exercise.
   c. _____Don't know.

6. At least once a week, do you engage in regular activity akin to brisk walking, jogging, bicycling, swimming, etc. long enough to work up a sweat, get you heart thumping, or get out of breath?
   _____No Why not?________________________________
   _____Yes How many times per week?_____
   Activity:__________________________________

7. When you are exercising in your usual fashion, how would you rate your level of exertion (degree of effort)? (Please circle one number.)

0	0.5	1	2	3	4	5	6	7	8	9	10
Normal	Very very weak (just noticeable)	Very weak	Weak	Moderate	Somewhat strong	Strong (heavy)		Very strong		Very very strong (almost maximal)	Maximal

5. On a usual weekday and a weekend day, how much time do you spend on the following activities? Total for each day should add to 24 hours.

	Usual Weekday Hours / Day	Usual Weekend Day Hours / Day
a. Vigorous activity (digging in the garden, strenuous sports, jogging, aerobic dancing, sustained swimming, brisk walking, heavy carpentry, bicycling on hills, etc.)		
b. Moderate activity (housework, light sports, regular walking, golf, yard work, lawn mowing, painting, repairing, light carpentry, ballroom dancing, bicycling on level ground, etc.)		
c. Light activity (office work, driving car, strolling, personal care, standing with little motion, etc.)		
d. Sitting activity (eating, reading, desk work, watching TV, listening to radio, etc.)		
e. Sleeping or reclining		

Seven-Day Physical Activity Recall

Interviewer ___________ Today is ___________ Today's Date ___________

1. Were you employed in the last seven days? 0. No (Skip to Q #4) 1. Yes
2. How many days of the last seven did you work? _____days
3. How many total hours did you work last in the last seven days? ______hours last week
4. What two days do you consider your weekend days? _______ ________ (mark days below with a squiggle)

DAYS

		1____	2____	3____	4____	5____	6____	7____
M O R N I N G	Moderate							
	Hard							
	Very Hard							
A F T E R N O O N	Moderate							
	Hard							
	Very Hard							
E V E N I N G	Moderate							
	Hard							
	Very Hard							
Total min per day	Strength: Flexibility:	____ ____	____ ____	____ ____	____ ____	____ ____	____ ____	____ ____

4a. Compared to your physical activity over the past three months, was last week's physical activity more, less, or about the same?
1. More
2. Less
3. About the same

APPENDIX D

THREE-DAY DIETARY RECORD

THREE-DAY DIETARY RECORD

Dietary Record Instructions

1. Use the Dietary Record Forms provided to record everything you eat or drink for 3 consecutive days – two weekdays and one weekend day.
2. Indicate the name of the FOOD ITEM, the AMOUNT eaten, how it was PREPARED (fried, boiled, broiled, etc.), and the TIME the food was eaten. If the item was a brand name product, please include the name. Try to be accurate about the amounts eaten. Measuring with measuring cups and spoons is best, but if you must make estimates, use the following guidelines:
   - Fist is about 1 cup
   - Tip of thumb is about 1 teaspoon
   - Palm of the hand is about 3 ounces of meat (about the size of a deck of cards)
   - Tip of thumb is about 1 ounce of cheese
3. Try to eat what you normally eat and record everything. The project will only be useful if you are HONEST about what you eat. The information you provide is confidential.
4. MILK: Indicate whether milk is whole, low fat (1 or 2%), or skim. Include flavoring if one is used.
5. VEGETABLES and FRUITS: One average serving of cooked or canned fruits and vegetables is about a half cup. Fresh whole fruits and vegetables should be listed as small, medium or large. Be sure to indicate if sugar or syrup is added to fruit and list if any margarine, butter, cheese sauce, cream sauce are added to vegetables. When recording salad, list items comprising the salad separately and be sure to include salad dressing used.
6. EGGS: Indicate method of preparation (scrambled, fried, poached, etc.) and number eaten.
7. MEAT/ POULTRY/ FISH: Indicate approximate size or weight in ounces of the serving. Be sure to include any gravy, sauce or breading added.
8. CHEESE: Indicate kind, number of ounces or slices, and whether it is made from whole milk, part skim, or is low calorie.
9. CEREAL: Specify kind, whether cooked or dry, and measure in terms of cups or ounces. Remember than consuming 8 oz. of cereal is not the same as consuming one cup of cereal. 1 cup of cereal generally weighs about 1 ounce.
10. BREAD and ROLLS: Specify kind (whole wheat, enriched wheat, rye, etc.) and number of slices.
11. BEVERAGES: Include every item you drink excluding water. Be sure to record cream and sugar used in tea and coffee, whether juices are sweetened or unsweetened and whether soft drinks are diet or regular.
12. FATS: Remember to record all butter, margarine, oil and other fats used in cooking or on food.
13. MIXED DISHES/ CASSEROLES: List the main ingredients and approximate amount of each ingredient to the best of your ability.
14. ALCOHOL: Be honest. Record amount in ounces. Specify with “light” or “regular” beer.

Dietary Record Form

Name: ________________________

Date:__________________________ (Please use a new copy for each day.)

FOOD ITEM	AMOUNT	TIME

Express approximate measures in cups (c), Tablespoons (T), teaspoons (t), grams (g), ounces (oz), pieces, etc.

APPENDIX E

SUPPLEMENTAL STUDY #1

SUPPLEMENTAL STUDY #1:
BODY COMPOSITION VARIABLES OF WOMEN PREVIOUSLY EXPOSED TO HRT COMPARED TO WOMEN NEVER EXPOSED TO HRT

Introduction

The years surrounding menopause are associated with both increases in body mass as well as total and central body fat (68, 86, 110, 115, 141). Body fat, especially located on the trunk, is associated with increased cardiovascular disease risk . Some evidence indicates that hormone replacement therapy (HRT) might attenuate or reverse the increases in body fat associated with menopause and thus decrease disease risk (49).

Purpose

The purpose of this study was to compare body composition variables of the women who had a history of HRT to those who had never taken HRT.

Methods

Forty-six women reported having taken some form of HRT previously while 47 women reported never having taken HRT. All of the subjects had discontinued hormone replacement therapy (HRT) at least two years prior to participating in the study. Protocol specifics are described previously in chapter 3 of this document, entitled "Manuscript".

Results and Discussion

The relationship between steps walked per day and body composition variables were different for those who had previously taken HRT (N=46) compared to subjects who never took HRT (N=47). Table E.1 gives descriptive statistics. Average steps per day were only significantly related to percent body fat and waist circumference in women with a history of taking HRT. In contrast, in women who had never taken HRT, all body composition variables were significantly inversely related to average steps walked per day (Table E.2). Independent t-tests revealed no significant differences in any of the body composition variables between the two groups (*P* values > 0.2).

These data imply that the use of exogenous estrogen may complicate the relationship between physical activity measured in steps per day and body composition. However, even in women with a history of HRT, the significant inverse relationship between steps per day and total fat and centrally located fat has important health implications including increased risk of cardiovascular disease and Type 2 diabetes. Because of the small number of subjects tested, more careful analysis of this finding is required.

Table E.1: Descriptive statistics

	HRT (N = 46)	No HRT (N = 47)
Steps	6765 ± 362	6861 ± 496
Age	61 ± 0.75	60 ± 0.93
BMI	27.6 ± 0.73	27.7 ± 0.98
Body fat (%)	41.5 ± 1.2	38.9 ± 1.5
Waist (cm)	89.4 ± 1.6	89.0 ± 2.4
Hip (cm)	106.8 ± 1.4	106.3 ± 2.1
WHR	0.84 ± 0.01	0.83 ± 0.01
Trunk fat (kg)	16.4 ± 0.6	15.5 ± 0.9

Steps·day^{-1}, average steps accumulated per day; BMI, body mass index; Body fat, body fat percentage; Waist, waist circumference; Hip, hip circumference; WHR, waist-to-hip ratio; Trunk fat, DXA trunk fat

Table E.2: Pearson correlations between average steps per day and body composition variables in subjects exposed to hormone replacement therapy vs. those who had never taken HRT

Variable	HRT (N=46) Correlation, *P*	No HRT (N=47) Correlation, *P*
BMI	-0.189, >0.05	-0.535, <0.0001*
Body fat (%)	-0.306, 0.039*	-0.405, 0.005*
Waist	-0.313, 0.034*	-0.566, <0.0001*
Hip	-0.245, >0.05	-0.527, <0.0001*
WHR	-0.240, >0.05	-0.321, 0.028*

* significantly correlated
BMI, body mass index; Body fat, body fat percentage; Waist, waist circumference; Hip, hip circumference; WHR, waist-to-hip ratio

APPENDIX F

SUPPLEMENTAL STUDY #2

SUPPLEMENTAL STUDY #2:
%BF - DXA COMPARED TO % BF - LOHMAN'S 3-C MODEL IN POSTMENOPAUSAL WOMEN

Introduction

In addition to estimating bone mineral density and bone mineral content, whole-body DXA scans can estimate %BF. Although DXA has not been established as a criterion method for assessing body composition, several studies have shown it to be valid compared to established body composition assessment techniques. For example, Prior et al. (89) compared whole-body DXA estimates of %BF to estimates from a 4-compartment model in a sample of 91 young men and 81 young women. They reported no significant difference between the two methods. In fact, they showed that DXA was more accurate in estimating %BF than hydrodensitometry compared to the 4-C model (89). Although some studies, such as the one cited previously, have validated DXA body composition estimates, further testing is needed to investigate the validity of DXA for measuring %BF in various populations including postmenopausal women.

Purpose

The purpose of this study was to compare %BF estimates of a Lunar whole-body DXA scan with those of Lohman's 3-compartment model in postmenopausal women.

Methods

Ninety-four women participated in the study. Each subject underwent a whole-body DXA scan which estimated %BF in addition to bone mineral density and bone mineral content. The bone mineral density measurement along with a body density measurement taken via Bod Pod were used in Lohman's 3-compartment model to estimate total body fat percentage. Protocol specifics are described previously in chapter 3 of this document, entitled "Manuscript". Paired t-test was used to compare results from the two methods. Significance was set at $P < 0.05$.

Results and Discussion

Table F.1 shows the body fat estimates for 94 postmenopausal women who underwent body composition testing via DXA and Lohman's 3-compartment model. A paired t-test reveals that the two methods for estimating body fat yield significantly different results. DXA overestimated %BF compared to Lohman's 3-compartment model by an average of 2.47%. Pearson product moment correlations revealed a significant, positive correlation between the two methods ($r = 0.894$, $P<0.001$). Therefore, there is a strong relationship between the two methods even though they produce different estimates.

These data imply that DXA is not an acceptable alternative for estimating %BF compared to Lohman's 3-compartment model in postmenopausal women. Although there was a strong positive correlation between the two methods, the %BF estimates were significantly different.

Table F.1: Comparison of %BF estimates from DXA and Lohman's 3-C model

Body Composition Model	Mean ± SE
DXA (%BF)	42.76 ± 0.81*
Lohman's 3-C (%BF)	40.37 ± 0.95

* = Significantly different compared to Lohman's 3-C model (*P*<0.001)

Therefore, a multi-compartment model like Lohman's 3-C model should be used to estimate %BF in this population if time and resources are available. Future research is needed to investigate the utility of DXA as a body composition assessment device.

VITA

Emily Martin Krumm was born in Maryville, Tennessee. Emily attended Maryville College and graduated with honors in 2000 with a Bachelor or Arts in Biochemistry. Following graduation, she completed emergency medical technician training and worked as an assistant for a local physician. During this time, she gained a greater appreciation for the impact that physical activity can have on health. In 2002, Emily entered the graduate program in Exercise Science at the University of Tennessee in pursuit of a master's degree in Exercise Physiology. Emily served as a graduate assistant in the Center for Physical Activity and Health in the 2002-2003 school year and as a graduate research assistant for Dr. Ed Howley in the 2003-2004 year. Emily will graduate suma cum laude receiving a Masters of Science degree with an emphasis in Exercise Physiology in August 2004 and was recently inducted into the Phi Kappa Phi honor society for her graduate work. Emily is currently working at Baptist Hospital of East Tennessee in the Cardiac Rehabilitation Department as an exercise physiologist.