PHYSICAL ACTIVITY, SEDENTARY BEHAVIOR, AND BONE HEALTH IN OLDER WOMEN

by

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A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy in Human Performance

Middle Tennessee State University
2013

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This dissertation is dedicated to my father Nobukiyo Ishikawa and

my mother Katsuko Ishikawa with much love and appreciation

for their never-ending care and discipline.

I write this in the hope that they will at least flip to this page…

ACKNOWLEDGEMENTS

This dissertation research could not have been completed without the contribution of each and every one of the following people that I have had the privilege to work with.

First, I would like to express my deepest appreciation to my committee chair, Dr. Don Morgan, for his patience and exclusive devotion to guiding and encouraging me through this process, I am so thankful; my motivation towards exploring new findings never faded. Thank you for setting the standards just high enough to always provoke my thoughts and to grow as a scholar. Thank you for never giving up on me. Your passion towards working with your students to produce quality and meaningful research will continue to inspire me.

Much of my appreciation also goes to my committee members, Drs. Minsoo Kang, Amy Jetton, and Vaughn Barry. Without Dr. Kang's expertise in measurement of human movements and data analysis, none of the studies could have been generated and completed with integrity. I thank Dr. J for sharing her knowledge in endocrinology and for bringing her unique perspectives to the table and Dr. Barry for expertise in physical activity assessment, which made this project more intriguing.

I must thank my closest colleagues, Youngdeok Kim, Dr. Joel Reece and Mr. Ryan Conners, for their generous hearts and willingness to always support and encourage me. Each of your contribution made a difference in my productivity. Many thanks are, of course, expressed to my undergraduate research assistants, Meghan Mace, Ellen Carrillo, and Sebastian Kimball, for their interests in research and commitment in providing continuous help during the data collection process.

I also very much thank the Exercise Science Program of MTSU which has brought me to where I am and for providing me with the opportunity to pursue this degree. To all of the faculty members of the HHP Department, supervisors, and colleagues who have trained me day-by-day to move closer to this goal, I cannot thank each and every one of you enough for being a part in my life here at MTSU. I am so thankful for having surrounded with such kind and influential people who will become my lifelong friends as I take another step forward into the world of higher education.

At last, I would like to thank all of my participants, my family, friends, and future family members for their endless love and for bringing joy to my life. May this piece of work be an expression of my many thanks to y’all.

ABSTRACT

The objective of this dissertation was to explore relationships among sedentary behavior, physical activity, and bone health in older women. The primary aim of Study 1 was to evaluate the contribution of self-report measures of sedentary behavior and physical activity (PA) to bone mineral density (BMD) and bone mineral content (BMC) at the femoral and spinal regions using surveillance data collected on more than 2,000 females aged 12 years and older. Findings from Study 1 revealed that a minimum of 60 minutes of daily moderate-to-vigorous physical activity (MVPA) was associated with increased BMD and BMC at the femoral neck and lumbar spine of adolescent females and greater amounts of self-reported sedentary behavior were related to lower femoral neck BMD and BMC levels. The focus of Study 2 was to determine if bone health status at the femoral and spinal regions could be predicted from objective measures of sedentary activity and physical activity in 44 healthy, post-menopausal women. Logistic regression analysis demonstrated that daily sedentary time and frequency of breaks in daily sedentary time were significant predictors of BMD at the femoral neck, but were not predictive of lumbar spine BMD. Furthermore, the degree of adherence to health-related PA guidelines was not a significant predictor of BMD at the femoral neck or lumbar spine. In Study 3, the impact of a 4-week, personalized behavioral intervention program designed to replace sedentary behaviors with weight-bearing, light-intensity physical activities (LIPA) was measured in 24 older females. No changes in daily sedentary time, daily frequency of breaks in sedentary time, or LIPA were observed following the intervention, but MVPA was significantly increased in participants who were contacted once a week for 20 minutes rather than twice a week for 10 minutes. In addition, a

significant positive correlation was observed between reduction in daily sedentary time and improvement in health-related quality of life. Results from this trio of studies provide support for future research and community-based efforts to more accurately quantify the contribution of sedentary behavior to bone health and further refine and implement behavioral change strategies to reduce sedentary behaviors in older adults and improve related health outcomes.

TABLE OF CONTENTS

Page

LIST OF TABLES. ix

LIST OF FIGURES. xi

LIST OF ABBREVIATIONS. xii

LIST OF APPENDICES xiii

CHAPTER I: PROJECT INTRODUCTION. 1

CHAPTER II: PREDICTION OF BONE MINERAL DENSITY AND CONTENT FROM MEASURES OF PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOR IN YOUNGER AND OLDER FEMALES. 6

- Introduction 6
- Methods 8
- Results 14
- Discussion 18
- References: Chapter II 24

CHAPTER III: PHYSICAL ACTIVITY, SEDENTARY BEHAVIOR AND BONE HEALTH IN POSTMENOPAUSAL WOMEN. 31

- Introduction 31
- Methods 32
- Results 39
- Discussion 49
- References: Chapter III 58
- Appendix: Chapter III 66

CHAPTER IV: FEASIBILITY OF REDUCING SEDENTARY BEHAVIORS IN NON-WORKING OLDER WOMEN. 72

- Introduction 72
- Methods 74
- Results 88
- Discussion 101
- References: Chapter IV 111
- Appendices: Chapter IV 118

CHAPTER V: PROJECT CONCLUSIONS..129

PROJECT REFERENCES 132

PROJECT APPENDICES 154

LIST OF TABLES

Page

CHAPTER II

Table 1:
Descriptive Statistics for Study Participants by Age Group 12

Table 2:
Results of Regression Analysis Predicting Bone Mineral Content and Bone Mineral Density at the Femoral Neck and Lumbar Spine 16

CHAPTER III

Table1:
Descriptive Statistics for Age, Weight, Sedentary Behaviors, Physical Activity, Medication Use, and Supplement Use by Bone Health at Femoral Neck 41

Table 2:
Descriptive Statistics for Age, Weight, Sedentary Behaviors, Physical Activity, Medication Use, and Supplement Use by Bone Health at Lumbar Spine 42

Table 3:
Classification Table for Femoral Neck and Lumbar Spine Bone Health Status................47

Table 4:
Results of Logistic Regression Predicting Bone Health Status at the Femoral Neck and Lumbar Spine...48

CHAPTER IV

Table 1:
Demographic Characteristics at Baseline by Groups..76

Table 2:
List of Suggested Weight-Bearing, Light-Intensity Physical Activities............................85

Table 3:
Pre- and Post-Intervention Values for Sedentary Behaviors and Physical Activity..........90

Table 4:
Post-Intervention and Post-Maintenance Values for Sedentary Behaviors and Physical Activity 98

Table 5:
Descriptive Statistics for Quality of Life and Instrumental Activities of Daily Living (IADL) Scores..100

LIST OF FIGURES

Page

CHAPTER IV

Figure 1:
Individual changes in daily sedentary time (minutes) from pre-intervention (Pre) to post-intervention (Post) for (a) the control group (CON) and pre-intervention to follow-up assessment for (b) intervention group 1 (G1), and (c) intervention group 2 (G2).............93

Figure 2:
Individual changes in frequency of breaks in daily sedentary time from pre-intervention (Pre) to post-intervention (Post) for (a) the control group (CON) and pre-intervention to follow-up assessment for (b) intervention group 1 (G1), and (c) intervention group 2 (G2)..........94

Figure 3:
Individual changes in light-intensity physical activity (minutes per day) from pre-intervention (Pre) to post-intervention (Post) for (a) the control group (CON) and pre-intervention to follow-up assessment for (b) intervention group 1 (G1), and (c) intervention group 2 (G2) 96

Figure 4:
Individual changes moderate- to vigorous-intensity physical activity (minutes per day) from pre-intervention (Pre) to post-intervention (Post) for (a) the control group (CON) and pre-intervention to follow-up assessment for (b) intervention group 1 (G1), and (c) intervention group 2 (G2) 97

LIST OF ABREVIATIONS

AWT =	Accelerometer wear time
BMC =	Bone mineral content
BMD =	Bone mineral density
BMI =	Body mass index
DXA =	Dual-energy x-ray absorptiometry
FBDST =	Frequency of breaks in daily sedentary time
HRQOL =	Health-related quality of life
IADL =	Instrumental activities of daily living
LIWB =	Light-intensity weight-bearing
MET =	Metabolic equivalent
MVPA =	Moderate- to vigorous-intensity physical activity
MVRPA =	Moderate- to vigorous-intensity recreational physical activity
NHANES =	National Health and Nutrition Examination Survey
NIH =	National Institute of Health
ORF =	Osteoporosis-related fracture
PA =	Physical activity
SBR-A =	Sedentary behavior record for adults
SPSS =	Statistical Package for the Social Sciences
VMHDS =	Vitamins, minerals, herbals, or other dietary supplements
VRPA =	Vigorous-intensity recreational physical activity

LIST OF APPENDICES

Page

CHAPTER III

Appendix A Brief Cognitive Assessment Tool 67

Appendix B Demographic and Health History Questionnaire 68

CHAPTER IV

Appendix A Demographic and Health Questionnaire 119

Appendix B Assessment Tool of Instrumental Activities of Daily Living..................123

Appendix C Assessment Tool of Health-Related Quality of Life 124

Appendix D Sedentary Behavior Record for Adults (SBR-A) 128

PROJECT

Appendix A Review of the Literature 155

Appendix B MTSU Institutional Review Board Approval 209

Appendix C Informed Consent Document for Research: Chapter III 210

Appendix D Informed Consent Document for Research: Chapter IV 213

CHAPTER I

PROJECT INTRODUCTION

Osteoporosis, a bone disease characterized by low bone mass and structural deterioration of bone tissue, currently impacts more than 10 million people in the United States and is expected to affect more than 14 million people by 2020 (Burge et al., 2007). Linked to increased mortality and morbidity (Alborg et al., 2010; Ho-Pham, Nguyen, Pham, Nguyen, & Ngyuen, 2011; Johnell & Kanis, 2006), more than two million osteoporosis- related fractures (ORF) were estimated to have occurred in 2005 at a total cost of more than 17 billion dollars (Alborg et al., 2010; Burge et al., 2007; Ioannidis et al., 2009). Current data suggest that middle-aged and older adults with hip or vertebral fractures are more likely to die within the first five years after having experienced a fracture compared to those without a history of fracture (Ioannidis et al., 2009). Among the elderly, a strong association exists between non-fatal fractures and reduced functional performance and loss of independence (Steven, Corso, Finkelstein, & Miller, 2006) and women with osteoporotic vertebral fractures report a diminished quality of life (Silverman, Minshall, Shen, Harper, & Xie, 2001). Despite the fact that one in three women and one in five men 50 years and older will likely experience an osteoporosis-related fracture, bone health is still one of the most commonly-ignored components of overall health in the United States (U.S. Department of Health and Human Services, 2004).

A dynamic tissue, the metabolism of bone is unique, insofar as the constant replacement of bone mineral occurs to increase or maintain bone density (Raisz, 1999;

Robling, Castillo, & Turner, 2006; Watts, 1999). It is well-established that mechanical loading on the bone, resulting from either weight-bearing activities or muscle contraction, increases the rate of bone turnover, producing a stronger and denser skeletal structure (Frost, 1989; Kohrt, Bloomfield, Little, Nelson, & Yingling, 2004; Moresth, Emaus, & Jorgensen, 2011). Regardless of whether an individual possesses known risk factors for osteoporosis (e.g., family history, age, sex, ethnicity, body mass index, smoking, calcium and vitamin D intake, medication use, sedentary lifestyle), research has clearly shown that engaging in appropriate physical activity during the pre- and early-pubsecent years contributes to greater bone mass levels, thus decreasing the potential of developing osteoporosis later in life (Gunter, Almstedt, & Janz, 2012; Karlsson, Nordqvist, & Karlsson, 2008; MacKelvie, Khan, & McKay, 2002; Ondrak & Morgan, 2007; Rizzoli, Bianchi, Garabedian, McKay, & Moreno, 2010). Current bone health recommendations for children and adolescents are to participate in high-impact activities, such as plyometric activities (e.g., jumping, gymnastics, soccer, and basketball) and resistance exercise at least three days a week for a total of 10 to 20 minutes daily, preferably spread out over multiple sessions within a day (Kohrt et al., 2004). During the adult years, it is recommended that individuals engage in relatively high-intensity bouts of resistance exercise or weight-bearing activity (e.g., tennis, stair climbing, jogging, basketball, volleyball) three to five days a week for 30 to 60 minutes to effectively maintain healthy levels of bone mass (Kohrt et al., 2004). In older adults, regular physical activity participation can reduce bone fractures and the risk of falling (Gregg, Pereira, & Caspersen, 2000). However, relatively few older men and women in the United States achieve current minimal physical activity recommendations, and 28% to 34% of adults

65 to 74 years of age are inactive (Brawley, Rejeski, & King, 2003; Agency for Healthcare Research and Quality, 2002). Activities to improve balance and prevent falls should be performed by older adults to supplement weight-bearing aerobic and resistance exercises designed to preserve bone mass (Kohrt et al., 2004). Generally speaking, relatively high-intensity physical activity maintained across the lifespan appears to be a major contributor to a healthy bone structure (Kohrt et al., 2004).

While the positive benefits of physical activity on bone health are well-documented in youth and adults, a paucity of data exists regarding the potential contribution of sedentary behavior, either separately or in combination with physical activity, on the density and strength of bone tissue. Sedentary behavior is generally defined as constant inactivity, the absence of whole-body movement, or simply sitting for extended time periods (Gardiner, Eaking, Healy, & Owen, 2011; Healy, Dunstan, Zderic, & Owen, 2008; Tremblay, Colley, Saunders, Healy, & Owen, 2010). Negative health consequences associated with sedentary living, such as impaired glucose and lipid metabolism (Ford, Kohl, Mokdad, & Ajani, 2005; Healy et al., 2008; Tremblay et al., 2010), greater all-cause mortality (Dunstan, Barr, Hamer, & Dunstan, 2010; Patel et al., 2010; Stamatakis, Hamer, & Dunstan, 2011), and clinically significant cardiac events such as myocardial infarction, stroke, and cardiovascular-related death (Stamatakis et al., 2011), have been highlighted in studies exploring the underlying physiology of physical inactivity. In youth, it has been suggested that recent increases in obesity and Type 2 diabetes may be partially explained by an inactive lifestyle (Biddle, Gorely, & Stensel, 2004). Sedentary behavior appears to have a mediating impact on bone metabolism, such that prolonged sedentary behavior creates an imbalance between bone resorption and formation, leading to a decrease in bone mineral density (Tremblay et al., 2010). Little is known, however, concerning the potential impact of reductions in sedentary time on bone health in female youth and older women. Given the importance of optimizing bone mass early in life (Gunter et al., 2012; Karlsson et al., 2008; MacKelvie et al., 2002; Ondrak & Morgan, 2007; Rizzoli et al., 2010), and in light of data revealing that 80% of those affected by osteoporosis are women (National Osteoporosis Foundation, 2011), it is of particular interest to document the impact of physical inactivity on the development and sustainability of bone health in both younger and older females.

Challenges which exist to raising physical activity levels of older adults include misconceptions regarding the intensity of physical activity required to provide health benefits and the existence of barriers to active living, such as pain, diminished health, environmental limitations, and lack of knowledge (Schultzer & Graves, 2004), all of which can hinder the ability of older adults from initiating positive lifestyle changes (Lee, 1993). Given these constraints, a promising approach to encouraging a more active lifestyle and reducing sedentary behaviors in older men and women is to progressively increase the time period devoted to improving functional mobility and participation in activities of daily living that can be more easily and continuously performed (Brawley et al., 2003). While the absolute intensity of these activities is not generally considered intense enough to maintain or improve bone health, the age-related decline in maximal exercise capabilities (Fleg et al., 2005; Goodpaster et al., 2006) raises the intriguing possibility that the relative intensity associated with increased performance of daily, weight-bearing living tasks might be sufficient to preserve or minimize bone loss in older adults. Such an approach aligns well with current physical activity guidelines (Garber et al., 2011) which suggest, that reducing sedentary time by engaging in short bouts of daily lifestyle pursuits, such as standing, should be a goal for all adults, irrespective of their physical activity profile. Because intervention studies targeting sedentary behavior are relatively scarce, additional research is necessary to develop, implement, and evaluate behavioral change approaches to assist older adults in initiating physical activity, reducing the amount of time spent in sedentary pursuits, and maintaining healthy lifestyle changes (Marcus et al., 2000; Owen, Healy, Matthews, & Dunstan, 2010; Sevick et al., 2007).

Against this backdrop, the overall goal of this dissertation was to document relationships among sedentary behavior, physical activity, and bone health in younger and older females. Specifically, the aims of this project were to 1) quantify the relative contributions of self-reported physical activity and sedentary behaviors to bone mineral density in adolescent females, young and middle-aged female adults, and older women; 2) document bone health status in older women from objective measures of sedentary behavior and physical activity status; and 3) establish the feasibility of reducing sedentary behaviors in older females.

CHAPTER II

PREDICTION OF BONE MINERAL DENSITY AND CONTENT FROM MEASURES OF PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOR IN YOUNGER AND OLDER FEMALES

Introduction

The effects of physical activity on metabolic and cardiovascular function in adults has been studied extensively (Haskell et al., 2007; Healy et al., 2008; Owen, Healy, Matthews, & Dunstan, 2008; and Sisson et al., 2009). To improve and maintain aerobic fitness, the *2008 Physical Activity (PA) Guidelines* (U.S. Department of Health & Human Services, 2013) recommend that adults engage in a minimum of 150 minutes per week of moderate physical activity (MPA) or 75 minutes of vigorous physical activity (VPA) or an equivalent combination of MPA and VPA spread out across the week. In terms of improving bone health, adults should participate in weight-bearing endurance activities three to five times a week and jumping and/or resistance exercise two to three times a week, resulting in a total of 30 to 60 minutes of daily combined physical activity (Kohrt, Bloomfield, Little, Nelson, & Yingling, 2004).

Peak bone mass is typically attained by the third decade of life and about 90% of peak bone mass is reached by the age of 18 years in females and 20 years in males [Gunter, Almstedt, & Janz, 2012; and National Institute of Health (NIH), 2011]. Thus, physical activity and exercise during childhood and adolescence are considered primary methods of enhancing skeletal development and preventing bone loss later in life (Gunter et al., 2012; and Hind & Burrow, 2007). While relationships between physical activity and various health parameters (i.e., blood pressure, lipid profile, obesity, and bone health) in youth have yet to be fully elucidated (Boreham & Riccoch, 2001), current recommendations are that children and adolescents participate in 60 minutes or more of daily moderate-to-vigorous-intensity aerobic activity (Strong et al., 2005) and engage in high-impact activities (such as jumping, hopping, gymnastics, and basketball) at least three days a week for a minimum of 10 to 20 minutes a day (Kohrt et al., 2004).

Independent of physical activity, sedentary behaviors (e.g, sitting, watching television, driving) have been shown to exert a negative impact on metabolism, vascular health, and bone mass in adults (Strong et al., 2005). Recent data indicate that a dose-response relationship exists between sedentary time and all-cause/cardiovascular disease mortality (Dunstan et al., 2010; Katzmarzyk, Church, Craig, & Bouchard, 2009; Warren et al., 2010). Metabolic dysfunction, characterized by increased triglyceride levels, lower insulin sensitivity, and decreased levels of high-density lipoprotein cholesterol, has also been linked to physical inactivity (Tremblay, Colley, Saunders, Healy, & Owen, 2010). Relative to bone health, a marked decrease in bone mineral density occurs after spending a significant amount of time in bed rest (Zerwekh, Ruml, Gottschalk, & Pak, 1998), suggesting that a reduction in sedentary time should accompany increases in moderate-to-vigorous-intensity weight-bearing activity to prevent and attenuate bone loss (Tremblay et al., 2010).

Although separate causal associations are present among physical activity, sedentary behavior, and selected health indices (Boreham & Riccoch, 2001), surprisingly little is known regarding the extent to which physical and sedentary behaviors separately or collectively influence health status across the lifespan, particularly with respect to skeletal health indices such as bone mineral content (BMC) and bone mineral density

(BMD). Hence, the purpose of our study was to evaluate the ability of physical activity and sedentary behavior to predict bone mineral density and content in younger and older females.

Methods

Sample

Data from 2,232 females aged 12 years and older collected as part of the 2007-2008 National Health and Nutrition Examination Survey (NHANES) were included in this analysis. Data analyzed in this project were publically available and downloaded from the Centers for Disease Control and Prevention (http://www.cdc.gov/nchs/nhanes/nhanes2007-2008/nhanes07_08.htm). Study participants were grouped into four age categories; a) adolescents (12 to 17 years; *n* = 337); b) young adults (18 to 39 years; *n* = 721); c) middle-aged adults (40 to 64 years; *n* = 847); and d) older adults (65 years and older; *n* = 327). Descriptive characteristics for the sample are shown in Table 1.

Study Variables

Body mass index. Body mass index (BMI; kg/m^2) was determined from height and weight measurements obtained by trained health technicians using standardized examination methods and a fixed stadiometer and calibrated floor scale, respectively. Both anthropometric values were electronically captured and automatically entered into the NHANES database to calculate BMI.

Physical activity level. Measures of physical activity were obtained from self-reported time spent in moderate- to vigorous-intensity recreational physical activities (MVRPA) (excluding work and transportation). Calculation of MVRPA was based on written responses to a physical activity survey. Vigorous-intensity recreational physical activity (VRPA) was evaluated by asking the following question (Question 1); "Do you do any vigorous-intensity sports, fitness, or recreational activities that cause large increases in breathing or heart rate like running or basketball for at least 10 minutes continuously?" Participants who answered 'yes' to Question 1 were requested to answer the following two questions: (a) "In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational activities?" (Question 2); and (b) "How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?" (Question 3). To determine the total amount of time per week spent in VRPA among individuals who answered 'yes' to Question 1, the time spent participating in VRPA on a typical day was multiplied by the number of days engaged in VRPA during the week. Weekly time involved in moderate-intensity recreational physical activity (MRPA) was quantified from answers to a set of three questions (Questions 4, 5, and 6) similar in format to the trio of questions addressing VRPA (see Questions 1, 2, and 3, above). Weekly time spent in MRPA and VRPA was summed to categorize individuals into one of two physical activity (PA) groups: (a) sufficient moderate- and vigorous-intensity recreational physical activity (S-MVRPA); and (b) insufficient MVRPA (I-MVRPA). More specifically, S-MVRPA was defined as 150 minutes or more per week of MVRPA (i.e., meeting the 2008 PA Guidelines for adults, while I-MVRPA was defined as 0 to less than 150 minutes a week (i.e., not meeting the 2008 PA Guidelines for adults). Respondents who answered 'no' to Questions 1 and 4 were also assigned to the I-MVRPA group. Because national physical activity guidelines recommend that youth participate in 60 minutes or more of MVRPA daily (U.S.

Department of Health and Human Services, 2013), total weekly MVRPA time was divided by seven to calculate mean daily time spent in MVRPA by adolescents. Adolescent girls who reported at least 60 minutes per day of MVRPA were assigned to the S-MVRPA group, whereas members of this group who engaged in less than 60 minutes per day of MVRPA were assigned to the I-MVRPA. Female youth who answered 'no' to questions concerning participation in MVRPA were also included in the I-MVRPA group.

Sedentary behavior. Self-reported daily sedentary behavior data were obtained by having participants answer this query: "The following question is about sitting or reclining at work, at home, or at school. Include time spent sitting at a desk, sitting with friends, traveling in a car, bus, or train, reading, playing cards, watching television, or using a computer. Do not include time spent sleeping. How much time do you usually spend sitting or reclining on a typical day?" The response to this question (in minutes per day) was entered into the regression model as a continuous variable.

Dietary intake. Consumption of milk products was determined from responses to the following question: "In the past 30 days, how often did you have milk to drink or on your cereal? Please include chocolate and other flavored milks as well as hot cocoa made with milk. Do not count small amounts of milk added to coffee or tea. Answer choices range from 0 "never," 1 "rarely," 2 "sometimes – once a week or more," and often "once a day or more." Dietary intake of calcium, Vitamin D, protein, and magnesium was also assessed by the question, "Have you used or taken any vitamins, minerals, herbals or other dietary supplements (VMHDS) in the past 30 days?" Participants who answered 'yes' to this question were asked to identify which VMHDS were taken and the amount ingested in the previous month.

Bone density assessment. Bone mineral content (BMC; g) and bone mineral density (BMD; g/cm^2) of the femoral neck and total lumbar spine (L1-L4) were measured by dual energy x-ray absorptiometry (DXA). Bone scans were performed with a Hologic QDR 4500A fan-beam densitometer (Hologic, Inc., Bedord, MA). Scanned data were analyzed using Hologic Discovery software, Version 12.4. BMC and BMD values were obtained for the femoral neck, trochanter, intertrochanter, Ward's triangle, and total femur from the proximal hip scan, and these values were available for each of the lumbar vertebrae (i.e., L1, L2, L3, and L4) and total lumbar spine. Due to their clinical relevancy in predicting risk for developing osteoporosis (Cummings, Bates, & Black, 2002; Lewiecki et al., 2008), femoral hip and total lumbar spine BMC and BMD values were chosen as dependent variables in this analysis.

Statistical Analysis

Physical activity levels (i.e., I-MVRPA and S-MVRPA) and self-reported time in minutes of sedentary behavior (e.g., sitting or reclining time, excluding sleeping) were used to predict BMC and BMD of the femoral and spinal regions after controlling for nutritional intake (self-reported milk consumption over the past 30 days), supplement intake (calcium, protein, vitamin D and magnesium), and body mass index. The SAS 9.2 SURVEYREG procedure was used to conduct regression analysis of the sample survey data and the ESTIMATE statement in SURVEYREG accounted for the multistage and complex nature of the NHANES sampling scheme. Statistical significance was established at $p \leq .05$.

Table 1

Descriptive Statistics for Study Participants by Age Group

	[a]All (*N* = 2,232)	Adolescents (*n* = 337)	Young Adults (*n* = 721)	Middle-aged Adults (*n* = 847)	Older Adults (*n* = 327)
Overall (%)		11.26 (0.95)	35.29 (1.57)	42.86 (1.25)	10.59 (0.72)
Race (%)					
White	69.67 (3.28)	60.76 (4.28)	64.37 (4.01)	72.83 (3.34)	83.99 (3.55)
Black	11.85 (1.90)	16.59 (2.28)	13.29 (2.27)	10.46 (1.83)	7.63 (2.28)
Mexican	8.12 (1.55)	12.24 (2.83)	10.88 (2.28)	5.94 (1.07)	3.38 (1.04)
Hispanic & others	10.36 (1.54)	10.41 (2.95)	11.46 (1.60)	10.77 (1.70)	5.01 (1.62)
BMI (%)					
Normal	42.59 (1.63)	69.31 (2.59)	43.57 (3.07)	35.83 (1.79)	38.23 (3.34)
Overweight	29.04 (1.50)	19.20 (2.77)	26.64 (1.80)	31.68 (2.54)	36.77 (2.93)
Obese	28.38 (1.35)	11.49 (2.73)	29.79 (2.62)	32.48 (2.17)	25.00 (2.86)
[b]MVRPA (%)					
I-MVRPA	62.38 (2.35)	42.50 (3.34)	57.56 (2.60)	67.95 (3.79)	77.00 (3.14)
S-MVRPA	37.62 (2.35)	57.50 (3.34)	42.44 (2.60)	32.05 (3.79)	23.00 (3.14)
Sedentary time (minutes/day)	338.04 (7.17)	463.97 (9.05)	325.51 (11.36)	320.66 (9.51)	316.33 (13.56)
BMC (g)					
Femur	29.56 (0.21)	28.54 (0.57)	30.54 (0.30)	29.61 (0.33)	27.20 (0.32)
Spine	57.87 (0.37)	52.57 (1.00)	61.01 (0.48)	58.12 (0.70)	52.06 (0.65)

(continued to next page)

Table 1 continued

	[a]All (*N* = 2,232)	Adolescents (*n* = 337)	Young Adults (*n* = 721)	Middle-aged Adults (*n* = 847)	Older Adults (*n* = 327)
BMD (g/cm^2)					
Femur	0.93 (0.01)	0.94 (0.01)	0.98 (0.01)	0.92 (0.01)	0.81 (0.01)
Spine	1.02 (0.01)	0.97 (0.01)	1.07 (0.01)	1.01 (0.01)	0.93 (0.01)
Nutrition intake					
Vitamin D (μg)	3.70 (0.11)	3.42 (0.32)	3.42 (0.20)	3.96 (0.16)	3.85 (0.19)
Calcium (mg)	844.39 (23.97)	821.37 (53.41)	853.64 (25.88)	856.54 (31.40)	788.82 (25.38)
Magnesium (mg)	257.64 (7.30)	207.16 (11.98)	255.26 (9.38)	276.33 (8.50)	243.63 (7.08)
Sugar (g)	108.34 (2.38)	117.21 (5.61)	112.93 (3.71)	106.67 (3.53)	90.43 (2.48)
Protein (g)	67.60 (1.24)	61.28 (2.33)	68.90 (1.42)	70.17 (2.06)	59.58 (0.95)
Milk consumption					
No Milk	16.02 (0.70)	12.69 (2.28)	12.32 (1.31)	18.74 (1.25)	20.89 (3.25)
≥1 glass/day	83.98 (0.70)	87.31 (2.28)	87.68 (1.31)	81.26 (1.25)	79.11 (3.25)

Note. adolescents= ages 12 to 17 years old, young adults = 18 and 39 years, middle-aged adults = 40 to 64 years, old adults = ages > 64 years; [b]MVRPA = self-reported moderate- to vigorous-intensity recreational physical activity (activities of at least 10 minutes continuously that cause a small to a large increases in breathing or heart rates); I-MVRPA = insufficient MVRPA (0 to r <150 $min \cdot wk^{-1}$); S-MVRPA = sufficient MVRPA (≥150 $min \cdot wk^{-1}$); BMC = bone mineral content; BMD = bone mineral density; BMI = body mass index; Sedentary time = self-reported sedentary time. All values are presented as a percentage (%) and standard error (SE) for categorical variables and mean and SE for continuous variables.

Results

Adolescent females

As depicted in Table 2, self-reported sedentary time was not a significant predictor of femoral BMC, femoral BMD, spinal BMC, and spinal BMD in female sedentary adolescents. In contrast, physical activity level was a significant predictor of all four bone parameters, as adolescent girls who engaged in at least 60 minutes a day of MVRPA displayed significantly greater femoral BMC, femoral BMD, spinal BMC, and spinal BMD values compared to girls in the I-MVRPA category.

Young adult females

Among young adult females, neither sedentary behavior or physical activity level were significant predictors of femoral BMC, femoral BMD, spinal BMC, and spinal BMD.

Middle-aged females

Sedentary time for middle-aged adults was not a significant predictor of femoral BMC, femoral BMD, spinal BMC, and spinal BMD. Relative to physical activity level, there was also no significant difference in any bone descriptor between middle-aged females engaged in I-MVRPA and S-MVRPA.

Older females

For older adults, sedentary behavior was a significant predictor of femoral BMC and femoral BMD, such that lower levels of femoral BMC and BMD were associated with increased sedentary time. However, sedentary time was not a significant predictor of spinal BMC and BMD. In contrast, physical activity level was not a significant predictor of femoral BMC, femoral BMD, spinal BMC, and spinal BMD, meaning that there was no difference in any bone measure between older adults in the I-MVRPA and S-MVRPA categories.

Table 2

Results of Regression Analysis Predicting Bone Mineral Content and Bone Mineral Density at the Femoral Neck and Lumbar Spine

	Adolescents (*n* = 337)	Young Adults (*n* = 721)	Middle-aged Adults (*n* = 847)	Older Adults (*n* = 327)
Femoral BMC (g)				
[1]MVRPA (mean (SE))				
I-MVRPA	28.37 (0.77)	30.42 (0.32)	29.01 (0.40)	26.40 (0.40)
S-MVRPA	30.97 (0.78)	30.66 (0.36)	29.54 (0.46)	26.64 (0.68)
P	.013	.576	.364	.738
[2]Sedentary minutes				
B (SE)	-0.02 (0.08)	-0.00 (0.03)	-0.02 (0.03)	-0.09 (0.04)
P	.777	.987	.575	.025
Femoral BMD (g/cm²)				
[1]MVRPA (mean (SE))				
I-MVRPA	0.95 (0.02)	0.98 (0.01)	0.91 (0.01)	0.80 (0.01)
S-MVRPA	1.01 (0.01)	0.99 (0.01)	0.92 (0.01)	0.81 (0.01)
P	.010	.397	.379	.644
[2]Sedentary minutes				
[3]*B* (SE)	-0.0004 (.0002)	-0.0001 (.0005)	0.0006 (.0007)	-0.0031 (0.0001)
P	.815	.791	.361	.036

(continued to next page)

Table 2 continued

	Adolescents (*n* = 337)	Young Adults (*n* = 721)	Middle-aged Adults (*n* = 847)	Older Adults (*n* = 327)
Spinal BMC (g)				
[1]MVRPA (mean (SE))				
I-MVRPA	52.16 (1.23)	60.45 (0.52)	56.94 (0.79)	50.16 (0.85)
S-MVRPA	56.45 (1.30)	60.63 (0.60)	56.49 (1.01)	50.19 (2.27)
P	.003	.848	.610	0.993
[2]Sedentary minutes				
B (SE)	0.19 (0.13)	0.07 (0.08)	-0.02 (0.09)	0.01 (0.08)
P	.166	.346	.875	.954
Spinal BMD (g/cm^2)				
[1]MVRPA (mean (SE))				
I-MVRPA	0.98 (0.01)	1.07 (0.01)	1.00 (0.01)	0.91 (0.01)
S-MVRPA	1.03 (0.02)	1.08 (0.01)	0.99 (0.01)	0.90 (0.03)
P	.012	.434	.572	.696
[2]Sedentary minutes				
[3]*B* (SE)	0.0013 (0.0017)	0.0010 (0.0007)	0.0007 (0.0012)	-0.0002 (0.0011)
P	.465	.191	.587	.839

Note. [1]Least square adjusted mean values of BMC and BMD; [2]Unstandardized beta values for sedentary minutes are adjusted as changes in BMC and BMD per 30 minutes of sedentary time. [3]Due to beta values being less than 0.01, four decimal places are reported for beta values of sedentary time for spinal and femoral BMD; MVRPA = self-reported moderate- to vigorous-intensity recreational physical activity (activities of at least 10 minutes continuously that cause a small to a large increases in breathing or heart rates); I-MVRPA = insufficient MVRPA (0 to <150 min·wk^{-1}); S-MVRPA = sufficient MVRPA (≥150 min·wk^{-1}); BMC = bone mineral content; BMD = bone mineral density; standardized estimates (*B*) are adjusted for milk consumption/supplement use and body mass index (BMI); SE = standard error.

Discussion

The purpose of this study was to quantify the influence of physical activity and sedentary time on bone health in younger and older females. A particular focus of this investigation was to document the extent to which physical activity and sedentary behaviors uniquely impact bone health. Knowledge gained from this project, which featured a large and ethnically-diverse sample varying in relative weight status, would be potentially useful in developing age-specific, activity-based interventions to improve skeletal health in females.

Physical activity, sedentary behavior, and bone health during adolescence

Female adolescents who engaged in sufficient amounts of MVRPA displayed significantly greater femoral BMC, femoral BMD, spinal BMC, and spinal BMD compared to participants who reported insufficient levels of MVRPA. This finding highlights the importance of performing a minimum of 60 minutes of daily weight-bearing activities during adolescence to increase bone mass during growth (Bass, 2000; French, Fulkerson, & Story, 2000; MacKelvie, Khan, & McKay, 2002) and echoes current belief that pre- and early-puberty are “windows of opportunity” for girls to optimize peak bone mass and possibly reduce the risk of osteoporosis-related fractures later in life (Biddle, Gorely, & Stensel, 2004; Gunter et al., 2012). Related to this point, data from the Iowa Bone Development Study (Janz et al., 2007), which revealed that MVPA was a significant contributor to bone strength at the femoral neck in children, also emphasize the potency of health-producing levels of physical activity as a means to optimize skeletal health in adolescent girls. From a long-term health perspective, accumulating evidence suggests that bone mass gained during early childhood can be maintained into adolescence and young adulthood (Baxter-Jones, Kontulainen, Faulkner, & Bailey, 2008; Janz et al., 2010; Scerpella, Dowthwaite, & Rosenbaum, 2011). To test this hypothesis, prospective longitudinal studies are needed to document the sustainability of gains in bone strength achieved by younger and older girls as a result of performing various types of MVRPA (Biddle et al., 2004). In this regard, school-based interventions have been shown to be effective in positively influencing children's activity behaviors and bone health (Biddle et al., 2004; Gunter et al., 2012) and a recent meta-analysis has underscored the benefits of having female youth engage in weight-bearing activity for three or more days of the week to enhance bone mineral accrual in the lumbar spine (Ishikawa, Kim, Kang, & Morgan, 2013).

While MVRPA was associated with greater femoral and spinal BMC and BMD values in adolescent girls, sedentary time was not a factor linked to any bone health outcome. This finding suggests that in females undergoing skeletal maturation, participation in sufficient amounts of MVRPA in this group may exert a stronger influence on bone mass accumulation than replacing sedentary pursuits with light-intensity physical activities.

Physical activity, sedentary behavior, and bone health during early-to-mid adulthood

Physical activity and sedentary behavior were not significant predictors of femoral BMC, femoral BMD, spinal BMC, and spinal BMD in adult women aged 18 to 54 years. Although speculative, these results may partly reflect data showing that the vast majority of bone mass in females is realized by 20 years of age and remains fairly constant until about 50 years of age (Kanis et al., 2008; Lebrun, 2006; NIH, 2011). Other lifestyle factors, such as smoking, alcohol consumption, and previous sporting activities

(Fehily, Coles, Evans, & Elwood, 1992; Beasley et al., 2010), and measures of reproductive function, such as age at menarche, use of oral contraceptives, and years of lactation (Fehily et al., 1992), may also influence bone health in younger and middle-aged women. In considering this possibility, Fehily and colleagues (1992) reported that current calcium and vitamin D use was associated with radial bone density in young adult females. Additionally, these researchers (Fehily et al., 1992) noted that radial bone density in adulthood was positively affected by past history of sport participation during childhood. In the present study, milk consumption and supplement use were controlled in the statistical model, but childhood physical activity and reproductive factors were not included as covariates. Moreover, sun exposure and age of menopause have been shown to impact bone health in premenopausal women (Cranney et al., 2007; Fehily et al., 1992; Welten, Kemper, Post, & Van Staveren, 1995).

Physical activity, sedentary behavior, and bone health in older adults

In our study, physical activity was not a significant predictor of femoral BMC and BMD and spinal BMC and BMD in women aged 65 years and older. However, sedentary behavior was a significant predictor of femoral BMC and BMD in this group. While relatively little is known regarding the contribution of sedentary behaviors on bone health in older women, our findings raise the intriguing possibility that bone loss in older females may be attenuated by replacing sedentary behavior with light-intensity, weight-bearing physical activity that can be easily incorporated into daily living routines. Based on findings presented in Table 2, it can be estimated that reducing sedentary time by one hour each day would lead to an increase in femoral BMD and BMC of 0.8% and 0.7%, respectively. While the relative magnitude of these changes in bone mineral density and content is not large, only a small percentage gain (~1.4%) in radial BMC values was noted after 10 months of general aerobic training supplemented with upper-body weight training in women aged 57 to 83 years (Rikli & McManis, 1990). Furthermore, data reported in two meta-analyses (Kelley, 1998; Wolff, van Croonenborg, Kember, Kostense, & Twisk, 1999) showed that more intense levels of weight-bearing physical activity and strength training increased femoral bone mass by only about 2% and reversed bone loss by just under 1% each year at the lumbar spine and femoral neck in pre- and post-menopausal women, while results from other meta-analyses (Martyn-St James & Carroll, 2006; Palombaro, 2005) of graded high-intensity exercise training and walking interventions demonstrated no effects on femoral neck BMD in older females. Viewed collectively, these findings lend support to the notion that replacing sedentary behavior with light-intensity physical activity may help to maintain or improve the bone strength of older women to a degree that is at least somewhat comparable to that observed by participating in moderate-to-vigorous exercise. From a practical standpoint, less-intense physical activity may be especially beneficial for older adults, who display age-related declines in maximal exercise capabilities (Fleg et al., 2005; Goodpaster et al., 2006) and physical function (Stevens, Corso, Finkelstein, & Miller, 2006), as well as an increased risk of bone fracture (Kanis, Johanson, Oden, & McCloskey, 2009; NIH Senior Health, 2011). This approach is also consistent with recent physical activity guidelines (Garber et al., 2011) which suggest that decreasing sedentary time should be a goal for all adults, irrespective of their physical activity profile. Because intervention studies targeting sedentary behavior are relatively scarce, additional research should be conducted to develop, implement, and evaluate behavioral change approaches to encourage older adults to become more active, reduce the amount of time spent in sedentary pursuits, and maintain healthy lifestyle changes (Marcus et al., 2000; Owen et al., 2010; Sevick et al., 2007).

Strengths and limitations

A major strength of this project was the ability to quantify the unique contributions of physical activity and sedentary time on bone mineral density and content in females representing nearly the entire spectrum of the human lifespan. Because of the descriptive nature of our analysis, however, causal relationships among a quartet of variables cannot be inferred and remain to be established by studies comparing the effects of light-, moderate-, and vigorous-intensity physical activity interventions on bone health in adolescent girls and younger and older female adults. Because only self-report measures of physical activity and sedentary behavior were employed in the current investigation, there is also a need to confirm our findings using objectively-determined measures of physical activity and sedentary behavior that can capture small physical movements and positional shifting and more precisely differentiate among sitting, lying, and standing activities typical of light-intensity movements (Tremblay et al., 2010).

Conclusions

In conclusion, findings from our study have shown that performing a minimum of one hour per day of moderate-to-vigorous recreational physical activity is associated with greater levels of femoral BMC, femoral BMD, spinal BMC, and spinal BMD in adolescent girls, while higher amounts of sedentary time are predictive of lower femoral BMC and BMD in older women. Viewed collectively, these findings provide support for the use of age-targeted physical activity interventions, such as increasing physical activity or reducing sedentary behaviors, to improve and maintain bone health during critical time periods for bone formation and loss in younger and older females.

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CHAPTER III

PHYSICAL ACTIVITY, SEDENTARY BEHAVIOR AND BONE HEALTH IN POSTMENOPAUSAL WOMEN

Introduction

Osteoporosis and osteoporosis-related fractures have become major worldwide health issues (Ahlborg et al., 2010; Ho-Pham, Nguyen, Pham, Nguyen, & Nguyen, 2011; Johnell & Kanis, 2006) due to their association with increased mortality and morbidity and the significant economic burden that these skeletal disorders impose on older adults (Ahlborg et al., 2010; Burge et al., 2007; Ioannidis et al., 2009). According to the International Osteoporosis Foundation (2013), it is estimated that one in three women over the age of 50 years will sustain an osteoporosis-related fracture.

While a substantial portion of the variance in peak bone mass is genetically predetermined (Judex, Donahue, & Rubin, 2002; Kanis & McCloskey, 1998; Ralston & de Crombrugghe, 2006), bone mass accumulation is also influenced by modifiable factors, such as physical activity and exercise (Kanis & McCloskey, 1998). The potential contribution of sedentary living to diminished bone health has also received greater attention, as recent data have shown that excessive sedentary behavior (e.g., prolonged sitting) can reduce gravitational loading on bone and lead to premature bone loss (Tremblay, Colley, Saunders, Healy, & Owen, 2010). In view of emerging evidence describing the negative effects of physical inactivity on human metabolism and physical function (Tremblay et al., 2010), further research is needed to document the unique impact of sedentary behavior on bone health in older adults, who exhibit high levels of sedentary time, decreased physical fitness, and reduced participation in regular physical activity (Taylor et al., 2004).

A recent analysis of survey data from the 2007-2008 National Health and Nutrition Examination Survey (NHANES) collected on females aged 12 years and older (Ishikawa, Kim, Kang, & Morgan, 2013) revealed that among females aged 65 years and older, sedentary behavior was a significant predictor of bone mineral density (BMD) and bone mineral content (BMC) at the femoral neck, but physical activity was not independently associated with BMD or BMC. While these findings highlight the unique contribution of sedentary behavior to bone strength in the aging population, the use of self-report measures may result in a underestimation or overestimation of daily physical activity (Prince et al., 2008) and a biased reporting of sedentary time (Clark et al., 2009). Consequently, the purpose of this study was to document the likelihood of developing osteopenia or osteoporosis at the femoral neck and lumbar spine based on objectively-measured, accelerometer-derived measures of physical activity and sedentary time in postmenopausal females.

Methods

Participants

Study participants (N = 50) were recruited using word-of-mouth and flyers that were displayed at local community centers, churches, fitness, and retirement homes. A short description of the study providing contact information for the primary investigator was also placed in the online version of the *Middle Tennessee State University Record* and the print and online versions of the Murfreesboro *Daily News Journal*, and *The Tennessean*. Individuals who responded to this multipronged recruitment effort were screened for eligibility to participate in this study. Inclusion criteria for the project included: (1) being a postmenopausal female at least 60 years of age; (2) the absence of medical conditions that could be aggravated by walking; and (3) the ability to recall and record daily physical activities based on results of a screening for cognitive impairment (Mansbach & MacDougall, 2012; see Appendix A) that was administered to each participant.

Once eligibility to participate in this study was confirmed, participants visited the exercise physiology laboratory for an initial meeting with the primary investigator. At this time, each participant read and signed an informed consent form explaining the purpose, description, benefits, and risks of the study. The research protocol was approved by the university Institutional Review Board.

Health history and dietary intake

Each participant completed a comprehensive health history and dietary assessment (see Appendix B) that included questions regarding (a) basic demographic information, general medical history, and bone health (Cauley et al., 2003; Feskanich, Willet, & Colditz, 2002; Kayalar et al., 2009); (b) menopausal status and age of menopause; (c) age of menarche; (d) number of births, age of first pregnancy, and years spent breastfeeding; (e) family history of osteoporosis, fracture history, and number of falls over the past year; (f) current use of hormonal replacement therapy and past use of other medications; (g) current and past history of smoking; and (h) history of bariatric surgery. In addition, participants were queried regarding their (i) consumption of carbonated drinks during childhood; (j) current and past use of dietary supplements (i.e., calcium, vitamin D, calcium + vitamin D, multivitamin, vitamin K, protein, and retinal);

and (k) current and past use of alcohol and caffeine (Feskanich et al., 2002). An interview-based approach was also employed to quantify (l) overall sedentary (sitting or reclining) time per day; (m) time spent performing light-, moderate-, and vigorous-intensity physical activity; (n) the number of days per week spent in muscle-strengthening activities; and (o) childhood sport participation.

Physical activity and sedentary behavior

Procedures. Physical activity and sedentary behaviors were documented using a waist-mounted, uniaxial ActiGraph GT1M accelerometer or a triaxial ActiGraph GT3X accelerometer (ActiGraph, Pensacola, FL). ActiGraph accelerometers are lightweight motion sensors that detect activity counts and step counts by capturing movements occurring in the vertical plane (GT1M) or movements in the vertical, anterior-posterior, and medial-lateral planes (GT3X). Extensive independent research has validated ActiGraph products against direct and indirect calorimetry and the doubly-labeled water (DLW) technique of estimating energy expenditure (Abel et al., 2008; McClain, Hart, Getz, & Tudor-Locke, 2010). Another unique feature of the ActiGraph motion sensor is its ability to differentiate among sedentary, light-, and moderate- to vigorous-intensity physical activity (Copeland & Esliger, 2009). The ActiGraph sensor was configured to store post-filtered and accumulated data in 60-second epochs over a consecutive 7-day period (Gardiner, Eakin, Healy, & Owen, 2011; Healy et al., 2008). Once the 7-day activity monitoring period was completed, the ActiGraph device was retrieved and motion data were downloaded using ActiLife Version 5 data analysis software created specifically for transmitting ActiGraph data to a computer. To standardize movement data obtained from the GT1M and GT3X accelerometers, only motion occurring in the vertical plane was analyzed.

Data Processing. Initial processing of accelerometer data included computing accelerometer wear time (AWT) and confirming that each participant wore the ActiGraph accelerometer at least four days for 10 or more hours a day. In determining AWT, any time frame containing 60 or more consecutive minutes of zero counts per minute, with allowance for one or two minutes of up to 100 counts per minute (Troiano et al., 2008), was not counted as a time period during which the accelerometer was worn and not included as part of AWT. Accelerometer readings were also scrutinized to confirm that the ActiGraph sensor was worn at least four days and for at least 10 hours each day. Following this preliminary analysis, data from one participant who did not wear the ActiGraph for a minimum of 10 hours a day on at least four days of the 7-day monitoring period were excluded from statistical analysis.

Established cut-points were used to define sedentary, light-intensity, and moderate- to vigorous-intensity physical activity. Each minute of data collection containing less than 100 movement counts was considered ‘sedentary’ activity (Gardiner et al., 2011; Hart, Ainsworth, & Tudor-Locke, 2011; Healy et al., 2008; Matthews et al., 2008) and operationally defined as sitting behavior. The accumulation of at least 10 consecutive minutes of less than 100 movement counts per minute was used as a threshold to define periods of sedentary time within a day, based on results from Kim & Kang (2013) showing that the accumulation of 1-minute activity bouts comprised of less than 100 movement counts per minute might not necessarily predict health outcomes. Using 1-minute epochs, activity counts ranging from 100 to 1040 counts per minute were considered ‘light-intensity physical activity’ (e.g., changing position from sitting to standing and walking a step) and activity counts equal to or greater than 1041 counts per minute were classified as ‘moderate-to-vigorous intensity physical activity’ (e.g., brisk walking, dancing, riding a bike, fast swimming, playing sports) (Centers for Disease Control & Prevention, 2012; Copeland & Esliger, 2009; Gardiner et al., 2011).

The final processing step of accelerometer data involved adjustment of the raw motion data for interindividual differences in daily wear time across days and the number of days of valid accelerometer data collection. To account for wear time variation across days, the number of wear-time adjusted minutes of moderate- to vigorous-intensity physical activity (MVPA) was calculated. Variation in the number of valid days (i.e., more than 10 hours of wear time per day) of AWT across participants was also accounted for by calculating a probability estimate of meeting the *2008 Physical Activity Guidelines for Americans* (i.e., accumulating a minimum of 30 minutes a day of MVPA at least five days a week) (U.S. Department of Health and Human Services, 2013) based on individual wear-time-adjusted MVPA data (Troiano et al., 2008).

Overall sedentary behavior was determined by averaging wear-time adjusted sedentary time across the number of valid days of accelerometer data collection. In addition to quantifying daily sedentary time, frequency of breaks in daily sedentary time was obtained by counting the total number of instances each day in which time blocks of 100 or more activity counts per minute were adjacent to time blocks containing less than 100 counts per minute (Healy et al., 2008). While daily sedentary time was computed based on a minimum of 10 minutes of sedentary activity, a 1-min epoch was used to calculate the number of breaks in daily sedentary time. The mean number of daily sedentary breaks was obtained by averaging the number of sedentary breaks per day across valid days of accelerometry monitoring.

Bone densitometry

Bone densitometry. After monitoring physical activity and sedentary behavior for seven consecutive days, participants completed a bone densitometry test. During this evaluation, bone mineral content (BMC; grams) and areal bone mineral density (aBMD; grams/cm^2) at the lumbar spine and femoral neck regions were quantified using dual energy x-ray absorptiometry (DXA; Hologic, Inc., Bedford, MA). DXA provides a non-invasive measurement of BMC and aBMD, two measures of bone health which have been commonly employed in studies predicting fracture risk in adults (Kayalar et al., 2009), and particularly older females, who are at heightened risk for osteoporotic fractures (Gunter, Almstedt, & Janz, 2012). DXA features imaging technology based on the use of minimal radiation beams at two energy levels to differentiate bone mineral from soft tissue (Kayalar et al., 2009). DXA-derived aBMD values are expressed as T-scores, which reflect the number of standard deviation scores below or above the average peak bone mass of a healthy adult population (Kanis et al., 2000; Kanis et al., 2008). Based on evaluation procedures established by the World Health Organization, a T-score of greater than -1.0 is defined as being in the normal or healthy range, while a T-score of -2.5 or below is defined as osteoporosis. T-scores falling between -1.0 and -2.5 are considered to be indicative of osteopenia, a condition wherein bone density is below the healthy range, but does not meet the criteria of osteoporosis (Cummings, Bates, & Black, 2002; Kanis et al., 2000; Kanis et al., 2008; Looker, Melton III, Harris, Borrud, & Shepherd, 2010). With respect to skeletal sites that are appropriate for DXA assessment, the lumbar spine and femoral neck are the two body regions most clinically relevant in older females, as both sites are typically fractured due to falls (Hamdy, Petak, & Lenchik, 2002). Consequently, regional scans of the lumbar spine and proximal hip were obtained in the present investigation.

Before assessing lumbar spine and femoral neck aBMD and BMC, the DXA machine was calibrated with a phantom supplied by the manufacturer of the DXA machine to assure quality control. Each bone scan was conducted by a licensed x-ray technician qualified to operate the bone densitometry unit. Before positioning the participant on the DXA scanning table, each participant was asked to remove any metal or jewelry and hospital scrubs were supplied to participants to wear during the DXA procedure, if necessary. To obtain the lumbar spine scan, participants were positioned in a supine position on the scanning table with their hips and knees flexed (a box was place underneath the participants' legs to minimize lumbar extension). Prior to scanning the proximal hip, the non-dominant leg was scanned to account for discordance in hip bone density between the non-dominant and dominant legs (Hamdy, Kiebzak, Seier, & Watts, 2006). The non-dominant leg was identified by asking each participant to kick a soccer ball, with the leg not used to strike the ball (i.e., the weight-bearing leg) classified as the non-dominant leg. If a participant had previously sustained a hip fracture or undergone hip replacement surgery in the non-dominant leg, the dominant leg was scanned. Participants were positioned with hip and knees extended on the scanning table while lying in the supine position with a slight hip internal rotation at approximately 15 degrees.

Data analysis

Descriptive data are presented as means ± standard deviation. Binomial logistical regression was used to predict bone health status (normal or osteopenia/osteoporosis, based on T-score criteria for aBMD) at the femoral neck and lumbar spine from three predictor variables (daily sedentary time, frequency of breaks in daily sedentary time, and the probability estimate of meeting health-related guidelines for MVPA) and five control variables (age, weight, osteoporosis medication use, estrogen therapy use, and current vitamin D and/or calcium supplement use) and to evaluate the ability of these variables to correctly classify participants into bone health status categories. The unique contribution of selected predictor and control variables to bone health status at the femoral neck and lumbar spine was also quantified after controlling for other variables in the model. Statistical significance was set at .05, and SPSS version 20.0 was used for all statistical analyses.

Results

Following an initial meeting with the primary investigator, two participants withdrew from the study. Data from three participants were also excluded from statistical analysis due to an insufficient number of days of step activity monitoring. Of the remaining 46 participants, two reported bilateral hip replacement surgery, resulting in data from 44 participants included in the binomial logistic regression analysis for femoral neck bone density. Similarly, because two of the 46 participants reported a history of lower back surgery that required placement of external hardware within the vertebrae, data from 44 participants were included in the regression analysis for lumbar spine bone density. Results from DXA scans taken within the past month were used for two participants due to their desire to avoid additional exposure to low-level radiation exposure.

Descriptive statistics for age, body mass index, daily sedentary time, frequency of breaks in daily sedentary time, physical activity level, medication and supplement use by bone health categories (i.e., normal, osteopenia, and osteoporosis) at the femoral neck and lumbar spine are shown in Tables 1 and 2, respectively. With respect to physical activity level, the overall mean probability estimate of meeting the *2008 Physical Activity Guidelines for Adults* (accumulating at least 10-minute bouts of moderate- to vigorous-intensity physical activity for at least 30 min per day on 5 or more days of the week) calculated across bone health categories was 0.34 .

Table 1

Descriptive Statistics for Age, Weight, Sedentary Behaviors, Physical Activity, Medication Use, and Supplement Use by Bone Health Status at the Femoral Neck (N = 44)

Variable	Normal (*n* = 13)		Osteopenia (*n* = 26)		Osteoporosis (*n* = 5)	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Femoral Neck						
Age	68.85	5.94	70.58	6.41	72.80	2.17
Weight (lbs)	177.65	38.47	142.41	16.51	151.60	20.79
Sedentary time (min·day^{-1})[1]	390.90	74.52	332.67	91.25	341.09	89.88
FBDST	84.34	15.43	88.97	17.23	86.58	17.79
MVPA (min·day^{-1})	35.17	18.06	47.88	31.58	39.12	20.62
PA probability estimate[2]	0.27	0.30	0.41	0.40	0.31	0.42
	n	%	*N*	%	*n*	%
Osteoporosis medication						
No	10	76.9	20	76.9	4	80.0
Yes	3	23.1	6	23.1	1	20.0
Hormone replacement						
No	9	69.2	22	84.6	5	100.0
Yes	4	30.8	4	15.4	0	100.0
Calcium/Vitamin D supplementation						
No	3	23.1	6	23.1	1	20.0
Yes	10	76.9	20	76.9	4	80.0

Note. *SD* = standard deviation; FBDST = frequency of breaks in daily sedentary time; MVPA = moderate-to-vigorous physical activity. [1]Adjusted for variation in ActiGraph wear time and does not include sleep time; [2]Probability estimates of participants accumulating 30 minutes of MVPA on at least five of seven days a week.

Table 2

Descriptive Statistics for Age, Weight, Sedentary Behaviors, Physical Activity, Medication Use, and Supplement Use by Bone Health Status at the Lumbar Spine (N = 44)

Variable	Normal (*n* = 22)		Osteopenia (*n* = 17)		Osteoporosis (*n* = 5)	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Lumbar spine						
Age	70.73	6.76	71.18	6.08	67.80	1.92
Weight (lbs)	162.27	36.35	143.76	19.43	148.90	16.38
Sedentary time (min·day^{-1})[1]	360.72	79.15	344.34	86.99	278.67	79.01
FBDST	82.81	17.68	89.34	14.76	99.40	13.46
MVPA (min·day^{-1})	40.47	20.66	41.89	23.86	65.97	49.28
PA probability estimate[2]	0.16	0.34	0.38	0.38	0.67	0.36
	n	%	*N*	%	*n*	%
Osteoporosis medication						
No	18	81.8	12	70.6	5	100.0
Yes	4	18.2	5	29.4	0	0.0
Hormone replacement						
No	18	81.8	14	82.4	5	100.0
Yes	4	18.2	3	17.6	0	0.0
Calcium/Vitamin D supplementation						
No	5	22.7	2	11.8	3	60.0
Yes	17	77.3	15	88.2	2	40.0

Note. *SD* = standard deviation; FBDST = frequency of breaks in daily sedentary time; MVPA = moderate-to-vigorous physical activity. [1]Adjusted for variation in ActiGraph wear time and does not include sleep time; [2]Probability estimates of participants accumulating 30 minutes of MVPA on at least five of seven days a week.

Impact of sedentary behaviors and physical activity on femoral neck bone health

Binomial logistic regression analysis was performed initially to estimate bone health status (normal or osteopenia/osteoporosis) at the femoral neck and lumbar spine from the three predictor variables (total daily sedentary time, frequency of breaks in daily sedentary time, and the probability of accumulating a minimum of 150 minutes of MVPA at least five out of seven days a week) and five control variables (age, weight, osteoporosis medication use, hormone replacement therapy, and current vitamin D and/or calcium supplement use). Because age, osteoporosis medication use, and hormone replacement therapy were not significant variables predicting femoral neck bone health status ($p > .05$) in the initial binomial logistic regression analysis, these variables were excluded from the model and another binomial logistic regression analysis was conducted. This second test of the regression model containing all three predictor variables and the remaining two control variables (i.e., weight and current vitamin D and/or calcium supplement use) against a constant-only model was statistically significant, χ^2 (5, N = 44) = 23.28, $p < .001$, indicating that this collective set of variables significantly distinguished between participants with normal femoral neck bone density and participants who displayed osteopenia or osteoporosis at the femoral neck. The Nagelkerke R^2 measure of strength of association revealed that 58% of the variance in femoral neck bone health status was explained by this 5-variable regression model. Examination of the classification table from the regression analysis demonstrated that 69% of participants who were categorized as having normal bone health and 90% of participants who were categorized as being osteopenic or osteoporotic at the femoral neck were classified correctly. Overall, 84% of participants were classified correctly with respect to bone health status at the femoral neck (Table 3).

Table 4 presents regression coefficients, Wald's statistics (a test of significance of each independent variable in the model), and odds ratios for the predictor and control variables in the logistic regression analysis for the femoral neck. According to the Wald criterion (the criterion value to reject the null hypothesis that a particular effect coefficient is zero), daily sedentary time and frequency of breaks in daily sedentary time significantly predicted bone health status at the femoral neck, *Wald* $(1, N = 44) = 4.72$, $p = .030$ and *Wald* $(1, N = 44) = 4.17$, $p = .041$, respectively. Specifically, this analysis revealed that a 1-unit increase in daily sedentary time and frequency of breaks in daily sedentary time reduced the odds of becoming osteopenic or osteoporotic by 2% and 10%, respectively, when controlling for other variables in the model. In contrast, the probability estimate of accumulating 30 minutes of MVPA on at least five of seven days of the week was not a significant predictor of femoral neck bone health status, *Wald* $(1, N = 44) = 0.26$, $p = .610$. Both control variables (weight and current calcium/Vitamin D use) were also significant predictors of femoral neck bone health, *Wald* $(1, N = 44) = 8.63$, $p = .003$ and *Wald* $(1, N = 44) = 4.33$, $p = .037$, respectively, after accounting for other variables in the model. Specifically, individuals who were heavier were less likely to become osteopenic or osteoporotic in the femoral neck region. Moreover, participants who reported current intake of Vitamin D and/or calcium supplements were less likely to exhibit osteopenia or osteoporosis at the femoral neck compared to those without current use of these supplements.

Impact of sedentary behaviors and physical activity on lumbar spine bone health

Binomial logistic regression analysis revealed no statistically significant difference between a test of the constant-only model and the full model containing three predictor variables (daily sedentary time, frequency of breaks in daily sedentary time, and the probability estimate of accumulating 30 minutes of daily MVPA at least five out of seven days a week) and two control variables (i.e., weight and current vitamin D and/or calcium supplement use) against a constant-only model, χ^2 (5, N = 44) = 7.32, p = .198. These findings revealed that this variable set did not distinguish between participants whose bone health was normal and those who were exhibited osteopenia or osteoporosis at the lumbar spine. The Nagelkerke R^2 indicated that 20% of the variance in lumbar spine bone health status was explained by the logistic regression model. Output from the regression analysis also revealed that 64% of participants who were categorized as having normal bone health and 73% of participants who were categorized as being osteopenic or osteoporotic at the lumbar spine were classified accurately. The average correct classification rate of lumbar bone health status was 68% (see Table 3).

Table 4 presents regression coefficients, Wald's statistics, and odds ratios for each predictor and control variable in the regression model. Based on the Wald criterion, overall daily sedentary time and frequency of breaks in daily sedentary time were not significant predictors of lumbar spine bone health status, *Wald* (1, N = 44) = 0.15, p = .697 and *Wald* (1, N = 44) = 0.14, p = .704, respectively. The probability estimate of accumulating 30 minutes of MVPA on at least five of seven days of the week was also not a significant predictor of lumbar spine bone health status, *Wald* (1, N = 44) = 1.15, p = .283. Likewise, both control variables (i.e., weight and current supplement use) were not significant predictors of bone health at the lumbar spine, *Wald* (1, $N = 44$) = 2.27, $p = .132$ and *Wald* (1, $N = 44$) = 0.18, $p = .674$, respectively.

Table 3

Classification Table for Femoral Neck and Lumbar Spine Bone Health Status

	Predicted bone health status		
Observed bone health status	Healthy	Osteopenic/osteoporotic	Percentage correct
Femoral neck			
Healthy	9	4	69.2
Osteopenic/osteoporotic	3	28	90.3
Overall			84.1
Lumbar spine			
Healthy	14	8	63.6
Osteopenic/osteoprotic	6	19	72.7
Overall			68.2

Note. N = 44; percentage correct = percentage correctly classified as having normal bone health or osteopenia/osteoporosis.

Table 4

Results of Logistic Regression Predicting Bone Health Status at the Femoral Neck and Lumbar Spine

Variable	*B*	*SE*	*Wald*	*OR*	*p value*
Femoral neck					
(Constant)	35.48	12.99	7.46	2.57E+15	.006
Daily sedentary time (min·day^{-1})	-0.03	0.01	4.72	0.98	.030
FBDST	-0.10	0.05	4.17	0.90	.041
[1]Physical activity	0.67	1.32	0.26	1.96	.610
[2]Calcium/Vitamin D use	-3.63	1.75	4.33	0.03	.037
Weight (lbs)	-0.09	0.03	8.63	0.92	.003
Lumbar spine					
(Constant)	2.97	4.92	0.36	19.40	.547
Daily sedentary time (min·day^{-1})	-0.00	0.01	0.15	1.00	.697
FBDST	0.01	0.03	0.14	1.10	.704
[1]Physical activity	1.04	0.97	1.15	2.82	.283
[2]Calcium/Vitamin D use	-0.38	0.90	0.18	0.68	.674
Weight (lbs)	-0.02	0.01	2.27	0.98	.132

Note. *N* = 44; [1]probability estimate of accumulating 30 minutes of MVPA on at least five of seven days a week; [2]Reference group = no use of vitamin D and/or calcium supplement; *B* = regression coefficient; Ca = calcium supplement; *SE* = standard error; *OR* = odds ratio; FBDST = frequency of breaks in daily sedentary time.

Discussion

Overview

The primary goal of this study was to document the extent to which bone health status in older women can be predicted from objective measures of daily sedentary time, number of breaks in sedentary behavior, and physical activity status. This cross-sectional investigation is a logical progression of recent work by Ishikawa, Kim, Kang, and Morgan (2012) demonstrating that a self-reported measure of sedentary behavior was a significant predictor of bone mineral density and bone mineral content at the femoral neck in females 65 years of age and older who were evaluated as part of the 2007-2008 NHANES survey. In the current study, the use of motion sensors provided a more quantitative method of assessing physical activity and sedentary behavior and reduced the likelihood that previous activity estimates may have been biased or inaccurate (Clark et al., 2009; Prince et al., 2008). In addition, the inclusion of frequency of interruptions in sedentary behavior as a marker of physical inactivity is novel and provided an opportunity to gain insight into how small increases in light-intensity physical activity spaced throughout the day may aid in preserving bone mineral density in older women.

Descriptive analyses revealed that 11% of participants exhibited osteoporosis at the femoral neck and lumbar spine and 59% and 39% of participants displayed osteopenia at the femoral neck and lumbar spine, respectively. These findings are consistent with recent NHANES data indicating a prevalence of 9% and 50% in osteoporosis and osteopenia, respectively, at the femoral neck or lumbar spine in females aged 50 years or older (Looker, Borrud, Dawson-Hughes, Shepherd, & Wright, 2012). As the prevalence of osteoporosis increases with age in adults (Looker et al., 2012), it is not surprising that mean levels of osteoporosis were slightly higher among our female participants, who were 60 years of age and older.

Gennuso, Gangnon, Matthews, Thraen-Borowski, and Colbert (2013) reported that average daily sedentary time in older adults was 9.4 hours per day, a value computed by accumulating 1-minute bouts containing less than 100 activity counts per minute. In the present investigation, a minimum of 10 minutes of sedentary behavior was used as a criterion to determine daily sedentary time because shorter periods of sedentary behavior might not necessarily be associated with negative health outcomes (Kim & Kang, 2013). Based on a 10-minute criterion, mean daily sedentary time in the present investigation was 5.9 hours. However, use of a 1-minute criterion for accumulating sedentary behavior yielded a daily sedentary time of 9.2 hours, a value nearly identical to that obtained by Gennuso et al. (2013) and 36% higher than the value for daily sedentary time calculated using a 10-minute criterion. The current lack of agreement regarding the minimal bout length of accumulated sedentary activity needed to determine daily sedentary time and the resultant impact on the calculation of this measure of physical inactivity highlights the importance of establishing standardized protocols to measure various attributes of sedentary behavior so that findings from different studies can be easily compared.

Moderate-to-vigorous physical activity (MVPA) data were obtained from accelerometry and included in the binomial logistic regression model to predict bone health in our female participants. As noted previously, probability estimates of meeting health-related physical activity guidelines (Troiano et al., 2008) were derived to account for interindividual variability in the number of valid days of physical activity assessment based on ActiGraph data. Findings from our investigation demonstrated an overall mean probability estimate of 0.34, signifying a relatively low adherence to health-related physical activity guidelines was displayed by our participants. According to the Centers for Disease Control and Prevention (2013), approximately 80% of adults do not meet federal physical activity recommendations and, as confirmed by data from the present investigation, older adults are even less likely to meet these formal activity guidelines. Hence, the non-significant contribution of MVPA levels to femoral neck and lumbar spine aBMD levels in the present study can be reasonably attributed to a generally limited adherence to recommended levels of moderate-to-vigorous activity, despite multiple efforts to recruit older women displaying a wide range of physical activity profiles.

Femoral neck bone health

Overall model. Results from the logistic regression model indicated that more than half of the variance in femoral neck aBMD was accounted for by a variable set consisting of daily sedentary time, number of daily sedentary breaks, the probability of accumulating a minimum of 150 minutes of MVPA, body weight, and calcium/Vitamin D supplement use. In addition, the regression model correctly classified the femoral neck bone health status of 84% of study participants. This level of accuracy exceeded the desirable level of contingency (i.e., 80% agreement between observed classification and predicted classification) needed to validate the legitimacy of the regression model (Safrit & Wood, 1995).

Sedentary behaviors. Daily sedentary time was a significant predictor of bone health status at the femoral neck in our sample of postmenopausal women. Specifically, followup analyses revealed that a 1-minute increase in daily sedentary time resulted in a 2% lower odds of osteopenia or osteoporosis at the femoral neck, after accounting for other variables in the model. While this finding seems counterintuitive, the use of ActiGraph motion sensors may have imposed some limitations in our ability to capture light-intensity activity (such as static standing) and led to an overreporting of sedentary behavior, thus confounding our results. Conversely, as mentioned earlier, it is also possible that our decision to base the accumulation of sedentary time on a minimal time block of 10 minutes may have resulted in an undercounting of daily sedentary time and obscured the association between daily sedentary time and femoral neck aBMD. In view of the preceding discussion, it is recommended that future studies documenting sedentary behavior utilize motion-sensing devices which can measure physical activity in three movement planes and differentiate among transitional movements between sedentary body positions (e.g., lying down, reclining, sitting) and light-intensity body positions, such as standing.

Results from the present study also indicated that frequency of breaks in daily sedentary time was a significant predictor of aBMD at the femoral neck, such that a 1-unit increase in the number of sedentary breaks was associated with a 10% decrease in the odds of osteopenia and osteoporosis, once the contribution of other variables in the regression model was taken into account. This finding is intriguing because it highlights the potential importance of avoiding prolonged bouts of sedentary behavior (e.g., sitting, reclining, lying) and engaging in numerous breaks from sedentary behavior throughout the day to sustain bone mineral density. In related work, Healy and associates (2008) reported that among middle-aged adults, more frequent interruptions in sedentary behavior was tied to a lower metabolic risk, independent of total sedentary time. In animal studies, multiple short bouts of high-impact bone loading performed on a daily basis have been shown to result in optimal bone formation in rats (Turner and Robling, 2003). As adequate rest and recovery are needed to restore the sensitivity of bone tissue to loading in humans, the frequency of physical activity may have a marked influence on bone strength, along with total volume of physical activity (Robling, Hinant, Burr, & Turner, 2002). While the absolute intensity of daily living activities is not usually considered sufficient enough to produce positive effects on bone development and maintenance (Kohrt, Bloomfield, Little, Nelson, & Yingling, 2004), the reduced functional capacities of older adults (Neder, Nery, Silva, Andreoni, & Whipp, 1999; Schultzer & Graves, 2004) may create a scenario in which light-intensity, weight-bearing activities that can be easily incorporated into daily living routines and spaced throughout the day (e.g., walking while talking on the phone or getting the mail, walking the dog, window-shopping, watering the lawn) may be an adequate stimulus to preserve or minimize bone loss. This functionally adaptive approach to maintaining bone health aligns well with the notion that adults of all ages should seek to reduce sedentary time by engaging in short bouts of daily weight-bearing lifestyle pursuits, regardless of their physical activity profile (Garber et al., 2011).

Body weight and current supplement use. With respect to weight and current Vitamin D/calcium supplement use, both variables were significant and independent predictors of femoral neck bone health status. These findings are consistent with data in the literature showing that greater body mass and use of Vitamin D and/or calcium supplementation are protective factors against developing osteoporosis in older adults (Dawson-Hughes, Harris, Krall, & Dallal, 1997; Gouvela et al., 2012; Tang et al., 2013).

Lumbar spine bone health

Overall model. In contrast with the femoral neck, wherein 58% of the variance in bone health status was accounted for by the logistic regression model, only 20% of the variation in lumbar spine aBMD was explained by daily sedentary time, number of sedentary breaks, the probability of meeting health-related physical activity guidelines for adults, current weight, and current calcium/Vitamin D supplement use. Additionally, the mean correct classification rate of lumbar spine bone health status using this 5-variable set was 68%, a value which was lower than the accepted level of contingency for validating a regression model (Safrit & Wood, 1995).

Sedentary behaviors. Data analysis revealed that daily sedentary time and frequency of breaks in daily sedentary time were not significant predictors of bone health at the lumbar spine in our sample of postmenopausal women. Moreover, the probability estimate of meeting MVPA guidelines did not contribute significantly to the estimation of lumbar spine bone strength in this group. This latter finding confirms previous research demonstrating a lack of association between subjectively-measured sedentary behavior and spinal bone mineral density in older women (Ishikawa et al., 2012).

Bone mineral density at the lumbar spine is typically increased by engaging in resistance training (Kohrt et al., 2004; Morseth et al., 2011). In a systematic review and meta-analysis conducted by Martyn St-James & Caroll (2006), a positive effect of progressive, high-intensity resistance training on BMD at the lumbar spine of females who were postmenopausal, regardless of concurrent use of hormone theory or calcium supplementation. However, regular walking, a physical activity that can be performed at a light- or moderate-to-vigorous intensity, did not have a significant effect on preserving bone mineral density at the lumbar spine in this group of older women. In explaining this latter finding, the authors suggested that the impact forces associated with walking may not have been large enough to adequately load the lumbar spine beyond that normally experienced during normal daily physical activities.

Body weight and current supplement use. With respect to weight and current vitamin D and/or calcium supplement use, both variables were not significant predictors of lumbar spine bone health status. Although speculative, other factors not included in the present analysis, such as lean body mass, past history of physical activity, past dietary intake, and being underweight or overweight/obese in the past, may help to predict current lumbar spine health in older females (Gunter et al., 2012).

Strengths and limitations

A novel aspect of our study was the inclusion of frequency of breaks in daily sedentary time as a descriptor of sedentary behavior. This decision was based on recent evidence showing that interruptions in sedentary routines are linked to improved metabolic health in adults (Healy et al., 2008). Based on our findings showing lower levels of osteopenia and osteoporosis among older women who take more breaks from sedentary behavior, studies should be conducted to evaluate the health impact of interspersing prolonged periods of sedentary activity with light-intensity physical activities of varying duration and to account for interindividual differences in daily sedentary time when expressing the number of breaks in daily sedentary time occurring each day. In making this recommendation, it should be noted that the use of accelerometers to quantify breaks in sedentary activity may be limited by an inability to contextualize activity breaks within the broader confines of prior and subsequent physical activity. Second, despite concerted attempts to maximize participant recruitment, our limited sample size prevented us from randomizing women into osteopenia and osteoporosis categories and contributed to the lack of significance of hormone and osteoporosis medication use in finalized regression models predicting bone health status at the femoral neck and lumbar spine. Hence, future research should incorporate larger samples of postmenopausal women displaying a wide range of sedentary behaviors, physical activity profiles, bone health levels, and medication use. As a final point, the lack of a sufficient number of ActiGraph accelerometers with capabilities of monitoring movement in three axes led to the decision to assess motion only in the vertical plane. Consequently, the ability to capture small physical movements, such as positional shifting (e.g., moving from sitting to standing) and categorize standing behavior as a light-intensity physical activity may have been restricted, at least to some extent. To remedy this situation, it is recommended that the activPAL, an accelerometer that assesses motion in the vertical, horizontal, and anterior-posterior planes, functions as an inclinometer (e.g., detects changes in position from sitting to standing or from sitting to lying), and accurately quantifies motion during stepping activities, be routinely employed in future investigations of sedentary behavior patterns and bone health status in older females.

Conclusions

In summary, results from our study demonstrated that daily sedentary time and frequency of breaks in daily sedentary time were significant predictors of bone health status at the femoral neck in postmenopausal women, while the probability estimate of adhering to health-related physical activity guidelines was not a significant predictor of bone mineral density at the femoral neck. At the lumbar spine, daily sedentary time, frequency of breaks in daily sedentary time, and level of adherence to recommended guidelines for physical activity were not significant predictors of bone health status in older females. To further explore this topic, additional studies featuring large numbers of postmenopausal females with diverse profiles of sedentary behavior, physical activity status, and bone health should be conducted to more fully explore the role of interruptions in sedentary behavior on bone mineral density in older females. Efforts should also be undertaken to develop and implement standardized testing protocols incorporating the use of appropriate measurement tools to assess sedentary behavior in laboratory and field-based settings so that a more complete understanding of the relationship between markers of physical inactivity and bone health among postmenopausal women can emerge.

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CHAPTER III Appendices

Appendix A

Brief Cognitive Assessment Tool

BCAT®-SF | BRIEF COGNITIVE ASSESSMENT TOOL

Brief Cognitive Assessment Tool Short Form

Name: ______________________ Today's Date: ______________________

DOB: ______________________

Gender: Female / Male

Education: ______________________

Examiner: ______________________

Total Score: ______________ / 21

Cut Score: 15/16 (dementia ≤ 15; non-dementia ≥ 16)

POINTS

ORIENTATION

☐ Year ☐ Month ☐ Day/Week ☐ State ☐ City ☐ Situation — _______ / 6

IMMEDIATE VERBAL RECALL

☐ Banana ☐ Justice ☐ Sara ☐ Bridge — _______ / 4

IMMEDIATE STORY RECALL

(Instructions: X ≥ 8 = 2 points, X = 4-7 = 1 point, X ≤ 3 = 0 points) _______ / 11 — _______ / 2

Carol / borrowed / $10 / from her brother / Jack / last week. / She couldn't pay him back / because she bought / a delicious / ice cream cone / at the circus instead.

EXECUTIVE

Cognitive Shifting: *(Instructions: X ≥ 8 = 2 points, X = 6-7 = 1 point, X ≤ 5 = 0 points)* — _______ / 2

1A - 2B - 3C - 4D - 5E - 6F - 7G - 8H - 9I - 10J

DELAYED STORY RECALL

(Instructions: X ≥ 8 = 2 points, X = 4-7 = 1 point, X ≤ 3 = 0 points) _______ / 11 — _______ / 2

Carol / borrowed / $10 / from her brother / Jack / last week. / She couldn't pay him back / because she bought / a delicious / ice cream cone / at the circus instead.

STORY RECOGNITION — _______ / 5

What was the name of the woman who borrowed money?	Carol	Mary	Sue
How much money did she borrow?	$15	$10	$16
What was the name of the woman's brother?	Robert	Tom	Jack
What did the woman buy?	Ice Cream	Sandwich	Soda
Where did the woman go?	Mall	Circus	Grocery

The BCAT-SF is a cognitive screening measure. It is an abbreviated version of the original BCAT. As such, definitive diagnoses should not be made based on this test alone. These results are based on the inputting of BCAT-SF item scores. The conclusions reported are the result of statistical analyses from data collected from psychometric research. All results are based on statistical probabilities, not certainties. Mansbach Health Tools, LLC is not responsible for formal diagnoses or treatments.

Appendix B

Demographic and Health History Questionnaire: CHAPTER III

Demographic and Health History Questionnaire (Study 1)

Official use

Participant ID:		Today's Date:	
Height (cm):	_______________ _______________	(avg.) _______________	
Weight (kg):	_______________ _______________	(avg.) _______________	

Please complete Parts I and II.

Part I: Your background

DOB: _________ / _________ / _________
Age (years): __________
Sex: ___________

Race/ethnicity (circle one):
- Asian/Pacific Islander
- Arabic
- Black/African-American
- Latino/Latina
- Native American
- White/Caucasian
- Other (please specify), ________________

Highest education you have completed (circle one):
- Middle school
- High school
- College/University
- Graduate School
- Other (please specify), ________________

Are you currently employed (circle one)?   Yes   No

If "Yes," are you working for pay or as a volunteer (circle one)?

For pay   As a volunteer

Please briefly describe your job, ____

Which best describes your annual family income?
- Less than $5,000
- Between $5,000 to $11,999
- Between $12,000 to $15,999
- Between $16,000 to $24,999
- Between $25,000 to $34,999
- Between $35,000 to $49,999
- Between $50,000 to $74,999
- $75,000 or more
- Don't know
- No answer

You are: Married
Never married
Divorced and remarried
Separated/Divorced
Widowed
In a relationship
Other (please specify), ________________________

Part II: Medical history & Dietary questions

Have you reached your menopause (circle one)? Yes No
If "Yes," age at menopause: _____

Age at menarche (years): _____

Number of births: _____

Age of first pregnancy: _____ Age of last pregnancy: _____

Breast feeding period (years): _____

Current use of **osteoporosis treatment medication** (circle one): Yes No
If "Yes," name(s) of medications (circle): Actonel (bisphosphonate)
Fosamax (bisphosphonate)
Didronel (bisphosphonate)
Evista (SERMs)
Forteo (PTH)
Protos (new)
Boniva (new)
Miacalcin (calcitonin)
Reclast (injection)
Other: _______________________

How many years have you been on **osteoporosis treatment medication**? __________ years

Are you on any **hormone replacement therapy (estrogen)**? Yes No

How many years have you been on hormone replacement therapy? _________ years

Chronic disease (circle one): diabetes mellitus
thyroid disease
hypertension
osteoarthritis
other forms of arthritis

Any additional medications: ____

Do you smoke cigarettes? (circle one) Yes No
If "No," do you have a history of smoking? Yes No
If "Yes," who long ago did you quit? _________ year ago

Have you ever had a bariatric surgery? Yes No

If "Yes," what year did you have it? _______

Number of falls in the past 12 months: _______

Have you ever broken a bone due to a simple fall? Yes No

If "Yes," when? Year ______ and body part(s) ___________________________

Are there female family member(s) with known or suspected poor bone health such as osteoporosis or osteopenia? Yes No

Have you ever had carbonated drinks during childhood? Yes No

Do you currently drink carbonated drinks? Yes No

Which of the following do you currently consume? (circle all that apply)

Supplements:

Calcium
Vitamin D
Calcium + vitamin D
Multivitamin
Vitamin K
Protein

Others:

Alcohol
Caffeine

Which of the following did you consume in the past? (circle all that apply)

Supplements:

Calcium
Vitamin D
Calcium + vitamin D
Multivitamin
Vitamin K
Protein

Others:

Alcohol
Caffeine

Investigator will interview you to complete the following -

Part III: Behavioral questions

Overall sedentary time.

The following question is about **sitting or reclining** at home, at work, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading or watching televisions], but do not include time spent sleeping.

How much time do you usually spend sitting or reclining on a typical day?

______ hours and ______ minutes per day

Current physical activity.
Following questions will ask you about the time you *currently* spend in physical activities including **light activities** [activities of daily living], **aerobic activities** [such as walking, dancing, swimming, aerobic exercise classes, bicycle riding, gardening, tennis, and/or golf] and **muscle-strengthening activities** [such as exercises with bands, weight machines, free weights, push-ups, lifting, carrying, yoga and/or Tai chi exercises].

On a typical day, how much time do you usually spend time in light activities [such as light housework]?

______ hours and ______ minutes per day

On a typical day, how much time do you usually spend time in activities that require **medium level of effort**? On a scale of 0 to 10, where sitting is 0 and the greatest effort possible is 10, medium level of effort is a **5 or 6** that produces increased breathing rate and heart rate.

______ hours and ______ minutes per day

On a typical day, how much time do you usually spend time in activities that require **high level of effort**? On the same scale as above, high level of effort is a 7 or 8 that produces large increases in breathing rate and heart rate.

______ hours and ______ minutes per day

During a typical week, how many days do you spend time in **muscle-strengthening activities** that involve all of the major muscle groups [such as the muscles of the legs, hips, chest, back, abdomen, shoulders, and arms]?

______ days per week

Activities during childhood.
Following questions will ask you about the time you spent in sitting and in physical activities **during childhood**.

During childhood, did you do any farm work? Yes No

During childhood, did you often play outdoor or indoor? Outdoor Indoor

During your childhood, did you participate in any sporting activities? Yes No

If yes, indicate the type of sports that you participated: ____________________________

How many days per week did you engage in the above activities?
______ days per week

CHAPTER IV

FEASIBILITY OF REDUCING SEDENTARY BEHAVIORS IN NON-WORKING OLDER WOMEN

Introduction

Advancements in technology and easier access to social media have led to the growing proliferation of sedentary behaviors, such as prolonged sitting at work and during leisure time (Healy et al., 2008). The negative health consequences of engaging in sedentary activity, characterized by an energy expenditure of 1.5 metabolic equivalents (METS) or less (Tremblay et al., 2010), include altered glucose and lipid metabolism (Ford, Kohl, Mokdad, & Ajani, 2005), higher all-cause mortality (Dunstan et al., 2010; Patel et al., 2010; Stamatakis, Hamer, & Dunstan, 2011; van der Ploeg, Chey, Korda, Banks, & Bauman, 2012), and clinically significant cardiac events (Stamatakis et al., 2011). In contrast, more interruptions in sedentary time have been associated with a decrease in metabolic risk, as reflected by lower measures of adiposity, triglyceride levels, and plasma glucose values (Healy et al., 2008).

While a rise in sedentary behaviors has been observed in adults of all ages (Gennuso, Gangnon, Matthews, Thraen-Borowski, & Colbert, 2013; Hamilton, Hamilton, & Zderic, 2007; Healy, Matthews, Dunstan, Winkler, & Owen, 2011), levels of physical inactivity are highest in older adults (Gardiner, Eakin, Healy, & Owen, 2011). Because aging is linked to reduced physical function, loss of muscle strength, greater morbidity and mortality, and diminished quality of life (Sattelmair, Pertman, & Forman, 2009), efforts aimed at reducing sedentary behaviors may lead to positive health outcomes in older adults. Along these lines, Gardiner and colleagues (2011) attempted to decrease sedentary behavior in older men and women by teaching them how to monitor sedentary time, set individualized goals, and formulate an action plan to reduce physical inactivity. Following a 45-minute session emphasizing participation in light-intensity physical activities and activities of daily living and the mailing of tailored feedback to participants based on their individual sedentary activity profiles, less time was spent in sedentary activities and the number of daily breaks in sedentary time occurring in the evening increased during the next six days of accelerometry monitoring. Kozey-Keadle, Libertine, Staudenmayer, and Freedson (2012) also reported that sedentary time was reduced by nearly 50 minutes per day among overweight office workers following implementation of a simple, week-long intervention featuring the use of behavioral modification strategies to assist in replacing sedentary behaviors with light-intensity activities.

Based on these limited, but promising findings associated with decreasing sedentary behaviors in adults, the focus of this project was to extend previous research by evaluating the impact of a month-long, individually-tailored lifestyle modification program on measures of sedentary behavior, physical activity, and quality of life in older women. From a practical viewpoint, knowledge gained from this study could provide insight regarding the unique health benefits of reducing sedentary behavior and increase our understanding of the combined effects of decreasing inactivity and increasing engagement in health-producing physical activity on mobility, functional fitness, bone density, and quality of life in aging adults (Gouveia et al., 2012; Sattelmair et al., 2012).

Methods

Participants

A total of 27 participants were recruited through word-of-mouth and flyers that were posted at local community centers, churches, retirement homes, and fitness facilities. A short description of the project with contact information for the principal investigator was also placed in the online version of the MTSU *Record* and print versions of the Murfreesboro *Daily News Journal*, and *The Tennessean.* The proposed sample size was based on results from a 2-tailed power analysis revealing that a minimum of 24 participants was needed to achieve a statistical power of at least 0.80 or greater with an estimated effect size of 0.50 at $p \leq .05$. Inclusion criteria for this project included: 1) non-working (i.e., retired or non-employed) female aged 60 years and older; 2) ambulatory with or without an assistive device (e.g., cane or a four-wheel walker); 3) free of medical conditions that could be aggravated by engaging in normal physical activity; and 4) the ability to recall daily physical activities based on results of a screening tool for assessing cognitive impairment (i.e., dementia) that was administered in-person (Mansbach & MacDougall, 2012).

Eligible participants were provided with a verbal and written explanation of the study and each participant read and signed a written informed consent form prior to participating in the project. The study protocol was approved by the university Institutional Review Board. After signing the informed consent form, two participants decided to withdraw from the study. Consequently, 25 participants completed the pre-intervention activity assessment.

Pre-intervention assessments

Assessment of general health history. A comprehensive health history and dietary assessment (see Appendix A) was completed by each participant that included questions about (a) basic demographic information and general medical history; (b) menopausal status and age of menopause; (c) age of menarche; (d) number of births, age of first pregnancy, and years spent breastfeeding; (e) family history of osteoporosis, fracture history, and number of falls occurring over the past year; (f) current use of hormonal replacement therapy and past use of other medications; (g) current and past history of smoking; and (h) history of bariatric surgery. In addition, participants were queried regarding their (i) consumption of carbonated drinks during childhood; (j) current and past use of dietary supplements (i.e., calcium, vitamin D, calcium + vitamin D, multivitamin, vitamin K, protein, and retinal); and (k) current and past use of alcohol and caffeine (Feskanich, Singh, Willett, & Colditz, 2002). An interview-based approach was also employed to quantify (l) overall sedentary (sitting or reclining) time per day; (m) time spent performing light-, moderate-, and vigorous-intensity activity; and (n) the number of days per week spent in muscle-strengthening activities. Participant characteristics, shown in Table 1, are descriptive of a somewhat overweight group of older women.

Table 1

Demographic Characteristics at Baseline by Groups

	CON (*n* = 8)		G1 (*n* = 9)		G2 (*n* = 8)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age (years)	72.9	9.3	75.2	12.4	69.6	9.2
Height (cm)	158.8	5.8	159.3	7.3	163.0	6.7
Weight (kg)	69.7	15.9	75.6	21.8	70.6	10.4
Body mass index (kg•m^{-2})	27.6	6.3	29.5	7.0	26.5	3.1

Note. CON = control group; G1 = intervention group 1; G2 = intervention group 2; *M* = mean; *SD* = standard deviation.

Instrumental activities of daily living (IADL). Physical function was assessed using the 8-item IADL scale (see Appendix B) developed by Lawton and Brody (1969). The IADL scale is a simple and valid tool to evaluate the functional status of elderly individuals (Applegate, Blass, & Williams, 1990) through personal interview. The interrater reliability of the IADL scale is reported to be 0.85 and the validity of this scale, when compared against four previously-validated scales (Mental Status Questionnaire, Physical Classification, Behavior and Adjustment rating scales, and Physical Self-Maintenance Scale), ranges from 0.41 to 0.61 (Graf, 2008). Information gleaned from this assessment tool can also be used to provide objective data to assist with targeted and individualized programs aimed at increasing the performance of IADLs in an aging population (Graf, 2008).

The IADL scale is comprised of eight activity domains, including (1) telephone usage, (2) shopping, (3) laundering, (4) transporting, (5) food preparation, (6) housekeeping, (7) medication use, and (8) handling of finances, all of which require more functional ability and added complexity compared to basic activities of daily living such as eating, maintaining continence, transferring, toileting, dressing, and bathing (Graf, 2008; Katz, 1983). The summary score for the IADL scale varies from ‘0’ (low function, dependent) to ‘8’ (high function, independent) for older women (Graf, 2008), and the scale can be used in community settings and hospital environments (Graf, 2008).

Health-related quality of life. Health-related quality of life was measured using the RAND 36-Health Survey Version 1.0 (RAND 36; RAND Health Communications, Santa Monica, CA). This survey assesses eight health concepts, including (1) physical functioning, (2) bodily pain, (3) role limitations due to physical health problems, (4) role limitations due to personal or emotional problems, (5) emotional well-being, (6) social functioning, (7) energy/fatigue, and (8) general health perceptions (Hays & Morales, 2001; Hays, Sherbourne, & Mazel, 1993). The RAND-36, which is based on the 36-item Medical Outcome Study Short Form (MOS SF-36) described by Ware and Sherbourne (1992), is widely used to measure health-related quality of life in younger and older adults (Hays & Morales, 2001). The reliability and validity of the RAND-36 have been evaluated in persons 17 years and older by using confirmatory factor analysis (VanderZee, Sanderman, Heyink, & de Haes, 1996) and the internal consistency of the RAND-36 is reported to be high (See Appendix C). All 36 survey items were evaluated in such a way that higher scores reflected a more positive value for each health concept. The original response scale was recoded onto a scale ranging from 0 to 100 and recoded scores for each health concept were averaged to determine the status of a particular health concept.

Physical activity level and sedentary behaviors. Physical activity level and sedentary behaviors were determined using either an ActiGraph GT1M or a triaxial ActiGraph GT3X waist-mounted, uniaxial accelerometer (ActiGraph, Pensacola, FL). ActiGraph accelerometers are widely-used motions sensors which have been validated in studies comparing estimated total daily energy expenditure against direct calorimetry (Rothney, Schaefer, Neumann, Choi,& Chen, 2008) and predicted energy expenditure during moderate- and vigorous-intensity physical activity against indirect calorimetry (Berntsen et al., 2010). A unique feature of the ActiGraph accelerometer is the capability to monitor activity counts, which can be used to categorize various intensities of physical activity (Butte, Ekelund, & Westerterp, 2012). Particularly among older adults, ActiGraph activity monitors have been employed to gather information on daily time spent in sedentary activity (e.g., sitting, working quietly, reading, and typing), light-intensity physical activity (e.g., changing position from sitting to standing and walking a step), and moderate-to-vigorous-intensity physical activity (e.g., brisk walking, mowing, jogging, playing sports) (Copeland & Esliger, 2009). In the current investigation, participants wore the ActiGraph GT1M or GT3X accelerometer, both of which were configured to store post-filtered and accumulated data in 60-second epochs over a consecutive 7-day period (Buman et al., 2010; Gardiner et al., 2011; Healy et al., 2008). Once the activity monitoring period was completed, the ActiGraph device was retrieved and motion data were downloaded using ActiLife Version 5 data analysis software. To standardize movement data obtained from the GT1M and GT3X accelerometers, only motion occurring in the vertical plane was analyzed.

Initial processing of accelerometer data involved computing accelerometer wear time (AWT) and confirming that each participant wore the ActiGraph accelerometer for at least one day that consisted of at least 10 hours of wear time (Tudor-Locke, Brashear, Johnson, & Katzmarzyk, 2010). In determining AWT, any time interval containing 60 or more consecutive minutes of zero counts per minute, with allowance for one or two minutes of up to 100 counts per minute (Troiano et al., 2008), was not counted as a time period during which the accelerometer was worn and not included as part of AWT. Activity count rates of less than 100 per minute over a minimum of 10 consecutive minutes were considered representative of sedentary time (Gardiner et al., 2011; Hart, Ainsworth, & Tudor-Locke, 2011; Healy et al., 2008; Matthews et al., 2008) and the number of minutes of sedentary time were accumulated each day. The accumulation of at least 10 consecutive minutes of less than 100 movement counts per minute was used as a threshold to define periods of sedentary time within a day, based on findings from Kim & Kang (2013) showing that the accumulation of 1-minute activity bouts comprised of less than 100 movement counts per minute might not necessarily predict health outcomes. Accumulated sedentary time averaged across valid days of activity monitoring to calculate daily sedentary time. Activity counts of 100 to 1040 counts per minute were classified as light-intensity activity and activity counts greater than or equal to 1041 counts per minute were classified as moderate- to vigorous-intensity physical activity (Copeland & Esliger, 2009; Gardiner et al., 2011).

The final processing step of accelerometer data involved adjustment of the raw motion data for interindividual differences in daily wear time across days and the number of days of valid accelerometer data collection. To account for wear time variation across days, the number of wear-time adjusted minutes of light-intensity activity and moderate- to vigorous-intensity physical activity (MVPA) were calculated. Variation in the number of valid days (i.e., more than 10 hours of wear time per day) of AWT across participants was also accounted for by averaging wear-time adjusted daily sedentary time, light activity, and MVPA.

In addition to quantifying daily sedentary time, frequency of breaks in daily sedentary time was obtained by counting the total number of instances each day in which time blocks of 100 or more activity counts per minute were adjacent to time blocks containing less than 100 counts per minute (Healy et al., 2008). While daily sedentary time was computed based on a minimum of 10 minutes of sedentary activity, a 1-min epoch was used to calculate the number of breaks in daily sedentary time. The mean number of breaks in daily sedentary time was obtained by averaging the number of breaks in daily sedentary time across valid days of accelerometry monitoring.

A self-report measure of sedentary behavior in adults [Sedentary Behavior Record for Adults (SBR-A)] developed and validated in our laboratory (Carter, Ishikawa, Farnsworth II, Barry, & Kang, 2013; see Appendix D) was modified and used as a secondary descriptor of sedentary activity. SBR-A and ActiGraph data were obtained during the same 7-day period. The SBR-A was structured in a manner similar to the 3-Day Bouchard Physical Activity Record (Bouchard et al., 1983), which features 15-minute time blocks into which participants insert numbers corresponding to specific sedentary activities which occur throughout the day. The specific sedentary behaviors listed in the SBR-A are (1) sleeping; (2) lying while using electronic devices; (3) lying while engaged in anything other than using electronic devices (with the exception of sleeping); (4) non-work-related sitting for transitioning; (5) sitting while using electronic devices; (6) sitting while engaged in anything other than using electronic devices (e.g., eating, reading a book, socializing); (7) work-related sitting for transitioning; (8) work-related sitting while using electronic devices; and (9) work-related sitting while engaged in activities other than using electronic devices. Participants were instructed to insert a number corresponding to a specific sedentary behavior (1 through 9, above) into a given time block if the sedentary behavior(s) occurred during a majority ($\geq$ 8 minutes) of the 15-minute time block. If situations in which more than one sedentary behavior was engaged in simultaneously during a 15-minute interval, participants were instructed to choose a number that best described the sedentary activity during this time period.

Once sedentary behaviors were recorded for seven days, SBR-A forms and ActiGraph devices were collected from each participant. To determine the total number of minutes per day spent in sedentary activity (as measured by the SBR-A), the number of 15-minute blocks that were filled in with letters matching specific sedentary behaviors were multiplied by 15. Daily sedentary time was summed across seven days and divided by seven to obtain mean daily sedentary time for each study participant.

Intervention protocol

Participant randomization. Using the covariate adaptive randomization method (Kang, Ragan, & Park, 2008), participants were assigned to one of the following groups: a control group (CON), a first intervention group (G1) or a second intervention group

(G2). While typical stratified randomization allows for a balance in covariates between groups, problems can arise when participants are assigned in the order they meet with investigators and are not identified prior to group assignment (Kang et al., 2008). Use of the covariate adaptive randomization addresses these concerns by enabling researchers to sequentially assign each participant into groups while maintaining balance across as many as four covariates, with up to four levels of each covariate across groups (Kang et al., 2008).

The covariate adaptive randomization employed in this study was generated using the Covariate Adaptive Randomization program (Kang & Park, 2007). In order to employ this randomization program, covariates must be categorical in nature. The four covariates that were considered in randomly assigning participants into CON, G1, and G2 groups were: (1) age, (2) BMI, (3) baseline measures of physical activity level, and (4) baseline measures of sedentary behavior derived from ActiGraph data. With respect to levels of each covariate, 1) age classifications were a) 65 to 70 years and b) 71 years and older; 2) BMI groupings included a) underweight/normal weight and b) overweight/obese; 3) levels of physical activity consisted of a) inactive (i.e., less than 30 minutes a day of moderate- to vigorous-intensity physical activity) and b) active (i.e., 30 minutes or more a day of moderate- to vigorous-intensity physical activity) categories; and 4) sedentary behaviors were categorized as either a) highly sedentary (i.e., more than 11 or more hours of sitting time per day) or b) moderately sedentary (i.e., less than or equal to 11 hours of sitting time per day).

Intervention. Within two to three days following completion of baseline data collection and participant randomization, members of all three groups (CON, G1, and

G2) met with the primary investigator for approximately 30 minutes. During this meeting, participants received feedback concerning their physical activity and sedentary behavior profiles and were provided with a general overview of how to reduce sedentary activity. During the next four weeks, members of the CON group did not receive any contact from the primary investigator (PI). In contrast, participants in G1 and G2 met with the PI and received an individually-tailored program aimed at progressively reducing sedentary behaviors. This program was based on a behavior change model (Brawley et al., 2003) and consisted of 1) identifying individual goals; 2) self-monitoring behaviors that need to be changed; 3) receiving feedback and information regarding progress toward goals; 4) self-evaluating progress that has occurred towards meeting individual goals; and 5) correcting or reinforcing behaviors to successfully achieve individual goals. Findings from the SBR-A self-report instrument were also reviewed to develop a personalized strategy which targeted the first component of the behavioral change model by identifying a daily goal for reducing sedentary time during Week 1 of the month-long intervention. To help accomplish this task, 15-minute time blocks on the SBR-A that were occupied entirely by sedentary behaviors were identified and participants were encouraged to replace these sedentary behaviors with appropriate light-intensity weight-bearing (LIWB) activities. Many of the LIWB activities were drawn from the intervention protocol of Kozey-Keadle and colleagues (2012) and considered representative of home- and work-based physical activities or activities tied to recreational pursuits or active transportation. Because the Kozey-Keadle et al. (2012) investigation focused on overweight, inactive office workers, the LIWB activity list was modified to include physical activity preferences more suitable to an aging and mainly retired population. In addition, activities from the Compendium of Physical Activity (Ainsworth et al., 2000) with an intensity rating less than 3.0 METs were provided to expand the range of light-intensity activity choices for participants in G1 and G2. Table 2 displays the list of weight-bearing, light-intensity activities provided to each participant.

Table 2

List of Suggested Weight-Bearing, Light-Intensity Physical Activities

At Home[1]

- Walk while talking on the phone
- If you have a dog, walk your dog an extra 10 minutes each day
- Do dishes by hand instead of using the dishwasher
- Stand during commercials and remain standing a minute or so after the end of the commercial
- Do a little extra housework
- Walk up and down each aisle when you grocery shop
- Walk up and down the stairs a couple times a day
- When you are carrying things in from the car, take more frequent trips with only one bag at a time
- Walk to get the mail

Recreation and Transportation[1]

- Choose active recreation that you can engage in with your friends and/or family
- Volunteer to walk a dog or play with the neighborhood kids
- Volunteer to plant trees or start a garden at home
- Go for a hike or picnic with your friends, family members, or grandchildren

Other activities extracted from the Compendium of Physical Activity[2]

- Arts and crafts, standing
- Ironing, standing
- Making your bed
- Putting away clothes, gathering clothes to pack, putting away laundry
- Talking, standing
- Singing, standing
- Playing a musical instrument while standing
- Putting away groceries and carrying groceries or packages
- Window-shopping
- Light-effort cleaning (dusting, straightening up, changing linen, carry trash out)
- Setting table, cooking or preparing food
- Playing with animals or children
- Touring/traveling/vacation involving walking and riding
- Watering the lawn or garden
- Mild stretching

Note. [1]Adapted from Kozey-Keadle et al. (2012); [2]Adapted from Ainsworth et al. (2000); intensity of listed activities ranged from 1.5 to 2.9 METS.

In addition to specifying a daily goal for decreasing time spent being physically inactive, the meeting with G1 and G2 participants in Week 1 addressed the second component of the behavior change model (i.e., self-monitoring) by providing participants with a copy of their completed baseline SBR-A form, asking them to identify four 15-minute blocks each day that were comprised of sedentary activities, and encouraging participants to replace sedentary activities with LIWB activities. To assist in this activity selection process, a rating of perceived exertion scale [ranging from '6' (no exertion at all) to '20' (maximal exertion)] was provided to each participant (Centers for Disease Control and Prevention, 2011) and they were asked to keep their perceived level of exertion between '7' (extremely light) to '12' (light).

In Weeks 2, 3, and 4 of the activity intervention, the PI contacted G1 and G2 participants personally or by phone. For G1 participants, contact with the PI occurred once a week for 20 minutes, resulting in a total of 60 contact minutes. For G2 participants, contact with the PI occurred twice a week (i.e., Monday and Thursday, Tuesday and Friday, Wednesday and Saturday, etc.) in 10-minute segments and also totaled to 60 participant contact minutes. During Week 2 of the intervention, the last three components of the behavior change model (i.e., receiving feedback and information regarding progress towards goals, self-evaluating progress that has occurred towards meeting individual goals, and correcting or reinforcing behaviors to successfully achieve goals) were explained to participants and the extent to which success had been achieved in meeting the Week 1 goal of reducing daily sedentary time was discussed. Study participants were also encouraged to identify a new daily goal for reducing sedentary time and brainstorm about feasible strategies to attain this activity goal.

In Weeks 3 and 4 of the intervention, material covered by the PI with G1 participants during each weekly 20-minute contact session included (1) progress made towards meeting individual activity goals; (2) correction or reinforcement of behaviors to successfully achieve activity goals; and (3) identification of new light-intensity goals and providing encouragement in achieving these activity goals. For G2 participants, a condensed version of information discussed with G1 participants was covered during the first 10-minute contact session, whereas specific aspects of the behavioral change model related to identifying and achieving new light-intensity activity goals was discussed during the second 10-minute contact session.

Maintenance period. Monitoring of sedentary behaviors using the ActiGraph accelerometer and SBR-A occurred at baseline and during Week 5 (post-intervention) for CON (n = 8), G1 (n = 9) and G2 (n = 8) participants. To evaluate whether intervention effects were maintained over the short-term, sedentary behaviors of G1 and G2 participants were evaluated using the ActiGraph motion sensor and SBR-A assessment during Week 9 (i.e., four weeks after the activity intervention was completed.

Data analysis

Descriptive findings are presented as means $\pm$ standard error (SE). Data were analyzed using SPSS version 20.0. A 3 x 2, group (G1, G2, CON) by time (pre-test, post-test) repeated-measures analysis of variance (ANOVA) was conducted to document changes in (1) daily sedentary time,(2) frequency of breaks in sedentary behavior, (3) light-intensity physical activity, (4) moderate-to-vigorous physical activity, and (5) health-related quality of life. To document short-term retention effects, another 2 x 2, group (G1, G2) by time (post-test, post-post-test) repeated-measures ANOVA was performed to evaluate changes in the four primary variables of interest (e.g., daily sedentary time, frequency of breaks in sedentary behavior, light-intensity physical activity, and moderate-to-vigorous physical activity). The association between changes in daily sedentary time and a) quality of life and b) the ability to engage in instrumental activities of daily living from pre- to post-tests was examined using Pearson-product moment correlation. A significance level was set at .05 for all statistical analyses.

Results

Baseline measures of sedentary behaviors and physical activity

One G1 participant became ill during the first week of intervention period and withdrew from the study; hence, a total of 24 participants (n = 8 per group) completed the post-intervention assessment. The mean AWT-adjusted daily sedentary time of the sample at baseline was 5.70 $\pm$ 1.69 hours per day and the number of daily sedentary breaks at baseline was 86 $\pm$ 21. Light-intensity and moderate-to-vigorous-intensity physical activities were performed for an average of 3.95 $\pm$ 0.97 hours and 37.34 $\pm$ 22.95 minutes per day, respectively. At baseline, no significant group differences in daily sedentary time, frequency of breaks in daily sedentary time, and duration of light-intensity and moderate- to vigorous-intensity physical activity (MVPA) were noted.

Pre- to post-intervention changes in sedentary behaviors and physical activity

Descriptive statistics for daily sedentary time, frequency of breaks in daily sedentary time, and time spent in light-intensity and MVPA are presented in Table 3. A 3 x 2 RM ANOVA revealed no group (CON, G1, G2) by time (pre- intervention: T1; post-intervention: T2) interaction for wear-time adjusted daily sedentary time, $F(2, 21) = 1.29$, $MSE = 2901.69$, $H\text{-}F\ p = .297$, $Partial\ \eta^2 = .11$. In addition, no significant interaction between group (CON, G1, G2) and time (T1, T2) was observed for frequency of breaks in daily sedentary time, $F(2, 21) = 0.25$, *H-F* $p = .778$, *Partial* $\eta^2 = .02$.

In considering time spent in light-intensity physical activity, no significant group (CON, G1, G2) by time (T1, T2) interaction was noted, $F(2, 21) = 1.05$, $MSE = .887.41$ *H-F* $p = .369$, *Partial* $\eta^2 = .09$. Relative to time spent in MVPA, a significant group (CON, G1, G2) by time (T1, T2) interaction was present, $F(2, 21) = 3.60$, $MSE = 179.64$ *H-F* $p = .047$, *Partial* $\eta^2 = .25$. Results from paired samples t-tests revealed that for CON, MVPA time at post- intervention was significantly lower than at pre-intervention. For G1, MVPA time at post-intervention was significantly greater than at pre-intervention, whereas for G2, no significant difference in MVPA time existed before and after the intervention.

Table 3

Pre- and Post-Intervention Values for Sedentary Behaviors and Physical Activity

Group	Time	Mean	Standard Error	95% Confidence Interval Lower-Bound	95% Confidence Interval Upper-Bound
Daily sedentary time (min·day^{-1})					
CON	Pre	290.18	37.72	217.98	362.38
	Post	318.88	30.67	255.10	382.65
	%Δ	**+9.0**			
G1	Pre	356.75	34.72	284.55	428.95
	Post	324.55	30.67	260.78	388.33
	%Δ	**- 9.0**			
G2	Pre	378.79	37.72	306.59	450.99
	Post	372.37	30.67	308.60	436.15
	%Δ	**-1.7**			
Frequency of breaks in daily sedentary time					
CON	Pre	92.86	7.38	77.52	108.20
	Post	88.10	5.69	76.26	99.93
	%Δ	**-5.1**			
G1	Pre	80.72	7.38	65.38	96.06
	Post	70.16	5.69	58.33	82.00
	%Δ	**-13.1**			
G2	Pre	84.26	7.38	68.92	99.60
	Post	75.90	5.69	64.06	87.74
	%Δ	**-9.9**			

(Continued to next page)

Table 3 continued

Group	Time	Mean	Standard Error	95% Confidence Interval Lower-Bound	Upper-Bound
Light-intensity physical activity (min·day^{-1})					
CON	Pre	256.24	20.62	213.35	299.12
	Post	213.47	16.96	178.21	248.74
	%Δ	**-16.7**			
G1	Pre	238.53	20.62	195.64	281.42
	Post	225.64	16.96	190.38	260.90
	%Δ	**-5.4**			
G2	Pre	216.88	20.62	174.00	259.77
	Post	194.19	16.96	158.93	229.46
	%Δ	**-10.5**			
Moderate- to vigorous-intensity physical activity (min·day^{-1})					
CON	Pre	44.77	8.22	27.69	61.86
	Post	29.05*	8.03	12.36	45.74
	%Δ	**-35.1**			
G1	Pre	36.26	8.22	19.17	53.34
	Post	45.81*	8.03	29.12	62.50
	%Δ	**+20.8**			
G2	Pre	31.01	8.22	13.92	48.09
	Post	28.19	8.03	11.50	44.84
	%Δ	**-9.1**			

Note. n = 8 per cell; %Δ = percent change from pre- to post-intervention; *values compared to pre-intervention values, significant at $p \leq .05$; CON = control group; G1 = intervention group 1 (one 20-minute session per week); G2 = intervention group 2 (two 10-minute sessions per week).

Maintenance of sedentary behaviors and physical activity

During the 3-week maintenance period (T2 to T3), contact was lost with one G1 participant, one G2 participant traveled overseas, and another G2 participant declined to complete followup testing. In addition, due to an inadequate period of accelerometer wear time (AWT), physical activity data from another G1 participant was excluded from analysis. Consequently, a total of 12 participants (n = 6 per group) were analyzed.

Descriptive statistics for sedentary behavior and physical activity data collected during the maintenance period are shown in Table 4. A 2-factorial ANOVA yielded no significant group (G1, G2) by time (T2, T3) interaction for daily sedentary time, $F(1, 10) = 3.10$, *H-F* $p = .109$, *Partial* $\eta^2 = .24$, power = .36. Figure 1 depicts patterns of change in daily sedentary time from T1 (pre-intervention) to T3 (post-maintenance) for G1 and G2 participants. Overall, a mean reduction in daily sedentary time of 7.15 $\pm$ 53.02 minutes and 41.05 $\pm$ 76.27 minutes occurred between T1 and T3 for members of G1 and G2, respectively.

With respect to frequency of breaks in daily sedentary time, ANOVA findings revealed no significant group (G1,G2) by time (T2,T3) interaction, $F(1, 10) = 0.02$, *H-F* $p = .863$, *Partial* $\eta^2 = .02$, power = .05. Figure 2 depicts general group trends in the frequency of breaks in daily sedentary time across T1, T2, and T3. The average reduction in frequency of breaks in daily sedentary time from the start of the intervention (T1) until end of the maintenance phase (T3) was 7 $\pm$ 16 for G1 and 7 $\pm$ 9 for G2.

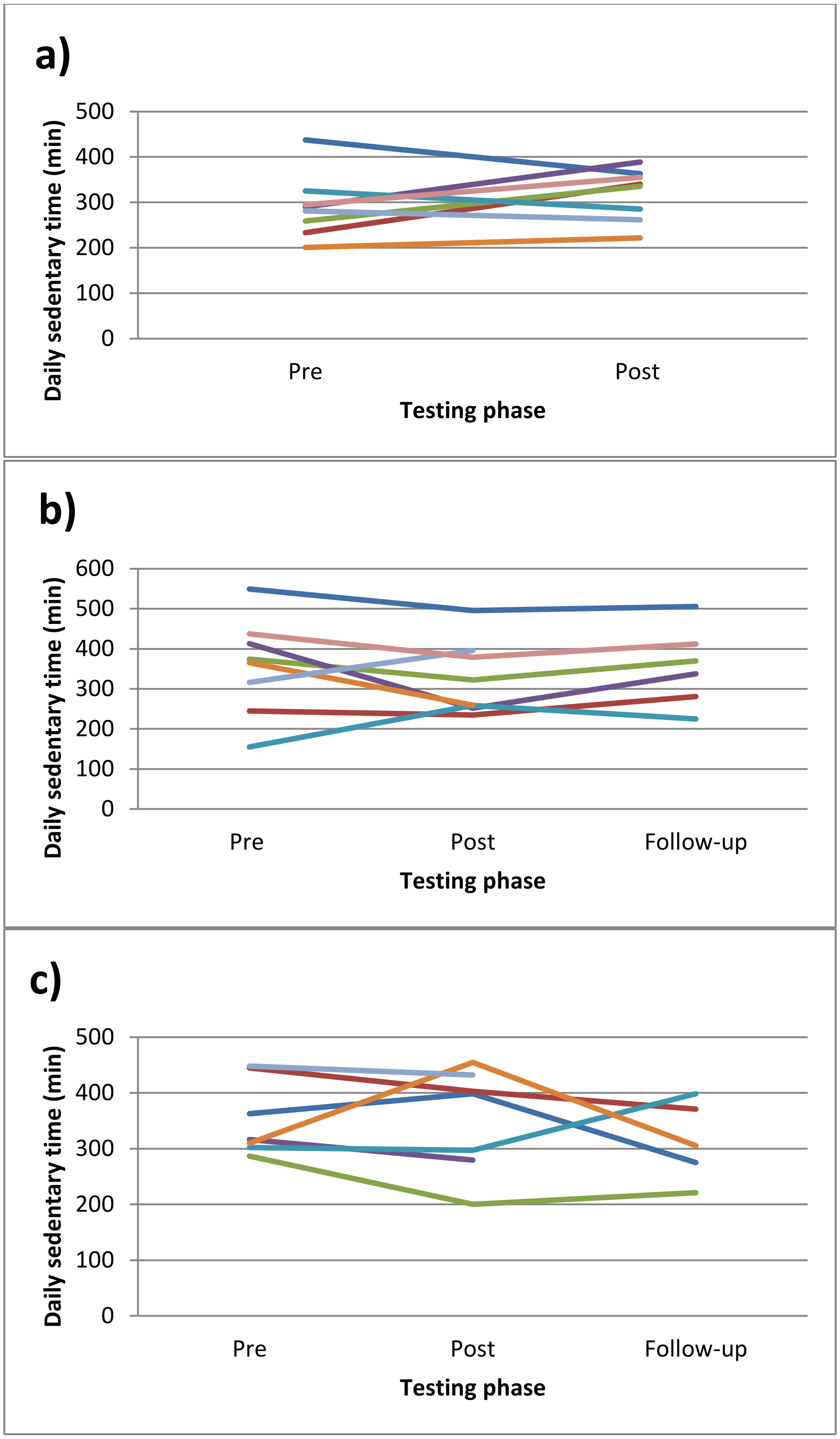

Figure 1. Individual changes in daily sedentary time (minutes) from pre-intervention (Pre) to post-intervention (Post) for (a) the control group (CON) and pre-intervention to follow-up assessment for (b) intervention group 1 (G1), and (c) intervention group 2 (G2).

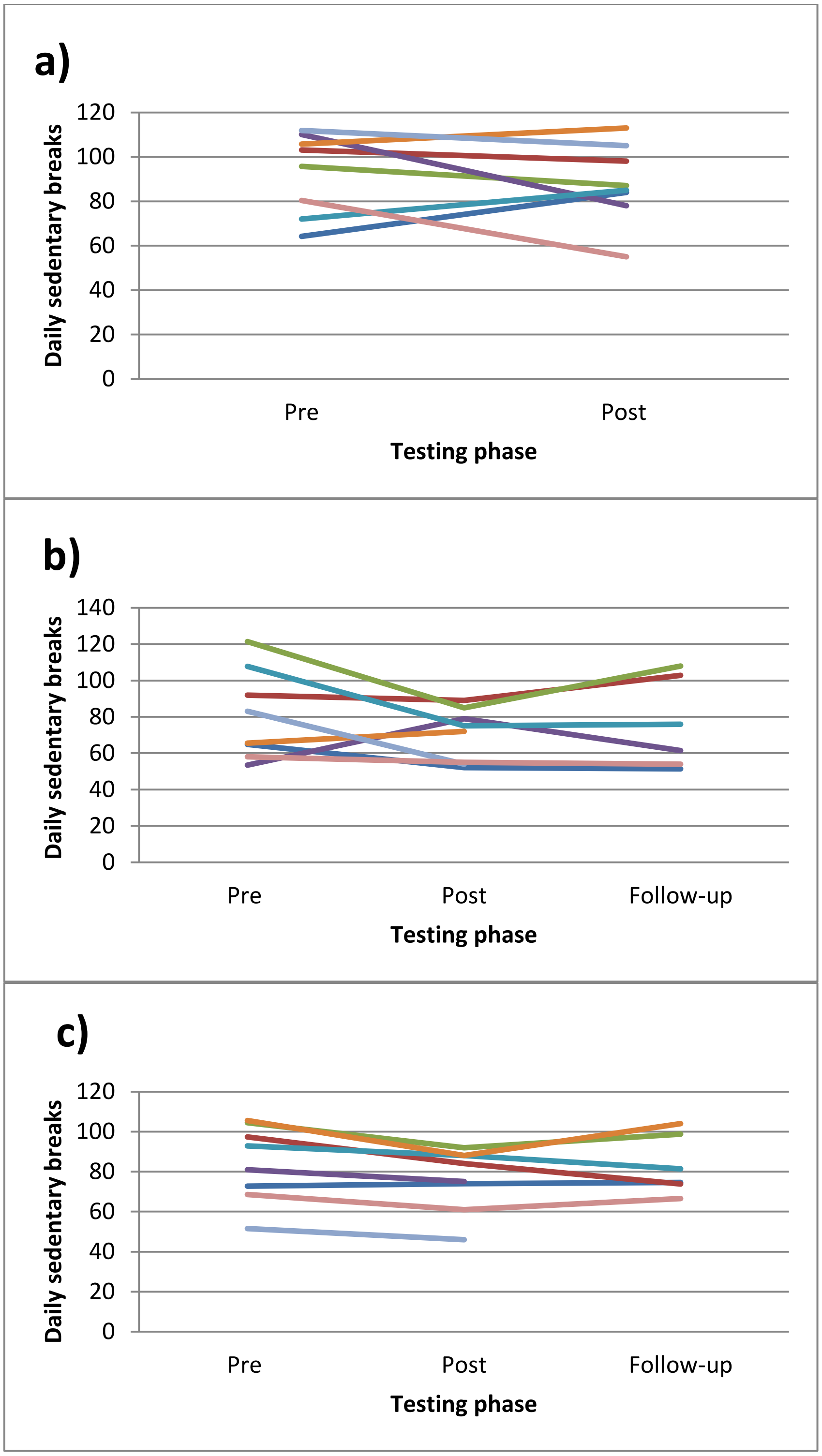

Figure 2. Individual changes in frequency of breaks in daily sedentary time from pre-intervention (Pre) to post-intervention (Post) for (a) the control group (CON) and pre-intervention to follow-up assessment for (b) intervention group 1 (G1), and (c) intervention group 2 (G2).

No significant interaction between group (G1, G2) and time (T2, T3), $F(1, 10) = 4.74$, *H-F* $p = .055$, *Partial* $\eta^2 = .32$, power = .50, was observed for light-intensity physical activity. Figure 3 displays general trends in light-intensity physical activity from the beginning of the intervention (T1) to the end of the maintenance phase (T3). On average, the amount of light-intensity physical activity performed by G1 was reduced by 20.20 $\pm$ 45.50 minutes a day from T1 to T3, while a mean increase in the volume of light-intensity activity of 11.1 $\pm$ 38.31 minutes per day was noted for G2 over the same time span.

Similar to light-intensity physical activity, no significant group by time interaction was evident for moderate- to vigorous-intensity physical activity (MVPA), $F(1, 10) = 4.73$, *H-F* $p = .055$, *Partial* $\eta^2 = .32$, power = .50. Changes in MVPA for both groups from T1 to T3 are shown in Figure 4. Over this time period, MVPA decreased by 5.48 $\pm$ 16.15 minutes per day for G1 and increased by 10.51 $\pm$ 19.34 minutes per day for G2.

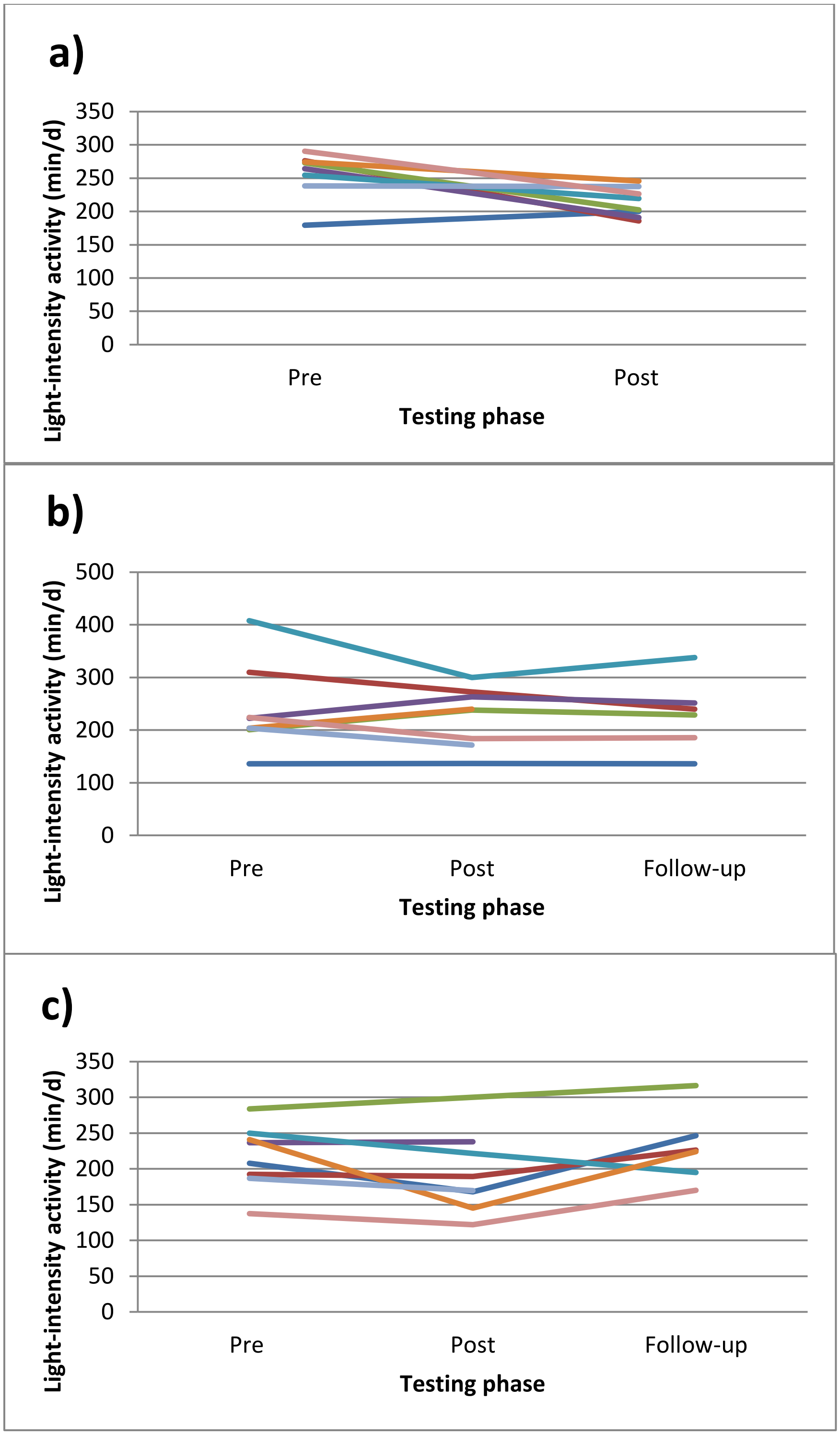

Figure 3. Individual changes in light-intensity physical activity (minutes per day) from pre-intervention (Pre) to post-intervention (Post) for (a) the control group (CON) and pre-intervention to follow-up assessment for (b) intervention group 1 (G1), and (c) intervention group 2 (G2).

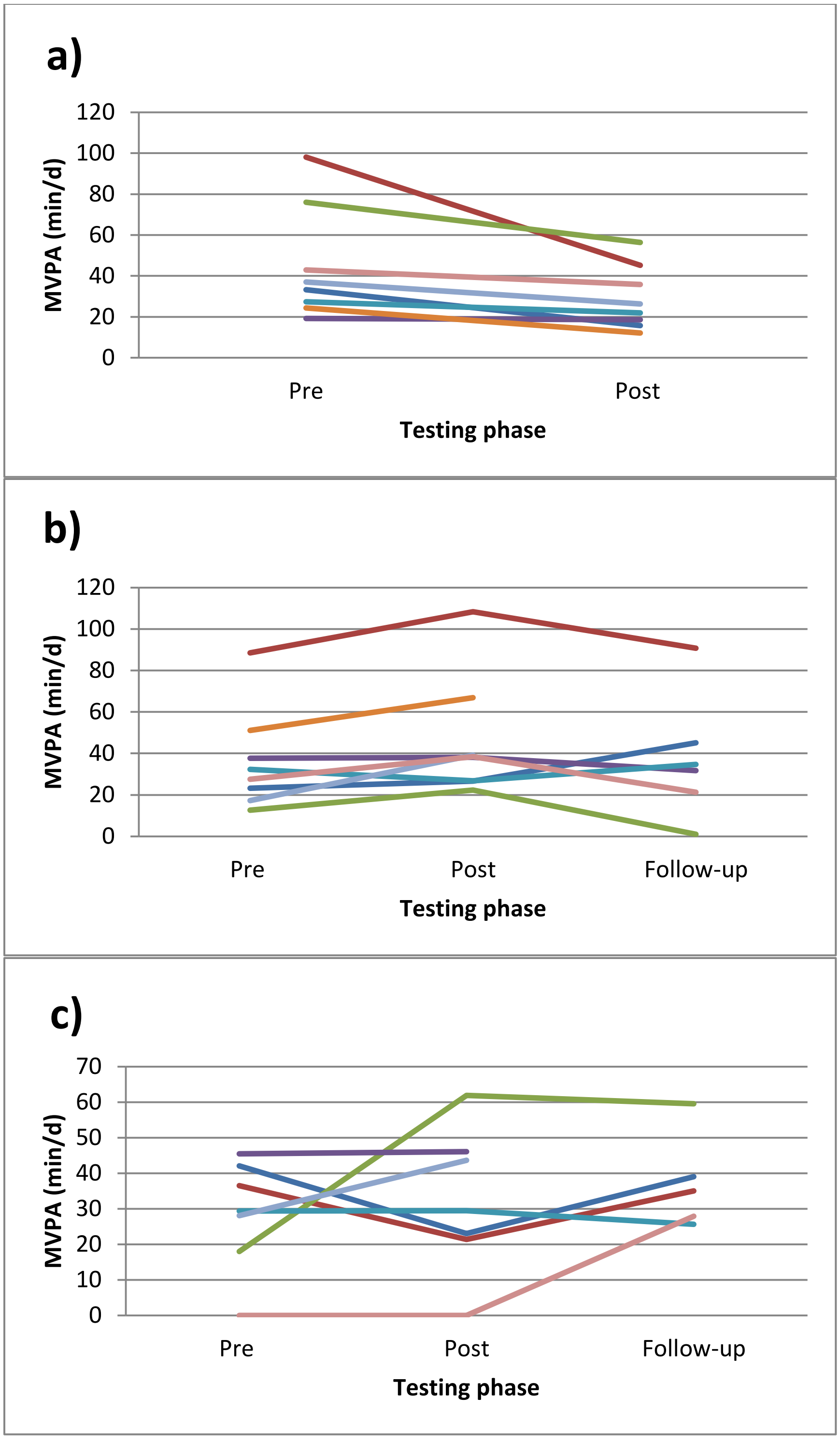

Figure 4. Individual changes moderate- to vigorous-intensity physical activity (minutes per day) from pre-intervention (Pre) to post-intervention (Post) for (a) the control group (CON) and pre-intervention to follow-up assessment for (b) intervention group 1 (G1), and (c) intervention group 2 (G2).

Table 4

Post-Intervention and Post-Maintenance Values for Sedentary Behaviors and Physical Activity

				95% Confidence Interval	
Group	Time	Mean	Standard Error	Lower-Bound	Upper-Bound
Daily sedentary time (min·day^{-1})					
G1	Post	323.54	43.50	226.61	420.46
	Follow-up	354.94	37.55	271.28	438.61
	%Δ	**+8.8**			
G2	Post	377.92	43.50	281.00	474.85
	Follow-up	336.63	37.55	252.96	420.29
	%Δ	**-10.9**			
Frequency of breaks in daily sedentary time					
G1	Post	72.56	5.60	60.09	85.04
	Follow-up	75.59	8.33	57.04	94.14
	%Δ	**+4.0**			
G2	Post	81.15	5.60	68.67	93.62
	Follow-up	83.20	8.33	64.65	101.75
	%Δ	**+2.4**			
Light-intensity physical activity (min·day^{-1})					
G1	Post	232.33	25.47	175.57	289.08
	Follow-up	229.91	24.36	175.64	284.19
	%Δ	**-1.0**			
G2	Post	190.96	25.47	134.20	247.71
	Follow-up	229.73	24.36	175.45	284.01
	%Δ	**+16.9**			

(Continued to next page)

Table 4 continued

Group	Time	Mean	Standard Error	95% Confidence Interval Lower-Bound	95% Confidence Interval Upper-Bound
Moderate- to vigorous-intensity physical activity (min·day^{-1})					
G1	Post	43.42	11.46	17.90	68.94
	Follow-up	37.42	9.49	16.28	58.56
	%Δ	**-13.8**			
G2	Post	22.63	11.46	-2.90	48.15
	Follow-up	39.59	9.49	18.46	60.73
	%Δ	**+42.8**			

Note. *n* = 6 per cell; %Δ = percent change from post-intervention to followup assessment; G1 = intervention group 1; G2 = intervention group 2.

Quality of life and instrumental activities of daily living

Descriptive statistics for quality of life and instrumental activity of daily living (IADL) are found in Table 5. Based on repeated measures ANOVA, no significant interaction was detected between group (CON, G1, G2) and time (T1, T2) for quality of life scores, $F(2, 19) = 0.11$, *H-F* $p = .896$, *Partial* $\eta^2 = .01$, power = .06, and for IADL scores, $F(2, 18) = 2.08$, *H-F* $p = .154$, *Partial* $\eta^2 = .19$, power = .37. In contrast, a significant positive correlation was observed between the amount of reduction in daily sedentary time and improvement in quality of life, $r = .439$, $p = .041$. However, no correlation emerged between the amount of reduction in daily sedentary time and change in IADL scores, $r = -.126$, $p = .586$.

Table 5

Descriptive Statistics for Quality of Life and Instrumental Activities of Daily Living (IADL) Scores

Variable	Group	Mean	Standard deviation
Quality of life			
	CON (*n* = 7)	644.62	83.96
Pre	G1(*n* = 8)	629.40	120.98
	G2(*n* = 7)	646.57	124.48
	Total	639.70	106.70
	CON (*n* = 7)	675.38	43.45
Post	G1(*n* = 8)	655.00	131.55
	G2(*n* = 7)	654.43	111.68
	Total	661.30	99.81
IADL			
	CON (*n* =8)	8.00	0.00
Pre	G1(*n* = 7)	7.57	0.79
	G2(*n* = 6)	7.83	0.41
	Total	7.81	0.51
	CON (*n* = 8)	8.00	0.00
Post	G1(*n* = 7)	8.00	0.00
	G2(*n* = 6)	7.83	0.41
	Total	7.95	0.22

Note. CON = control group; G1 = intervention group 1; G2 = intervention group; Pre = pre-intervention; Post = post-intervention.

Discussion

While positive changes in lifestyle behaviors are often recommended to prevent disease and disability or improve health, the process of increasing home- and community-based physical activity and maintaining positive changes in daily activity patterns can be challenging, especially for older adults (Brawley et al., 2003; Garber et al., 2011). Findings from second study in this dissertation (Ishikawa et al., 2013) revealed that the probability of adhering to current health-related physical activity guidelines was not a predictor of femoral neck bone mineral density in postmenopausal women. However, as reported in the first study of this dissertation (Ishikawa et al., 2013), self-reported daily sedentary time was a significant predictor of bone health status at the femoral neck in older women. Against this backdrop, the primary aim of this feasibility study was to quantify the immediate and short-term residual effects of a 4-week, activity-based, behavioral change intervention on sedentary behaviors in healthy, non-working ambulatory older women. To our knowledge, this is the first study to evaluate the impact of a behavioral intervention on sedentary behaviors in older adults that has lasted for more than seven days. In addition to documenting aspects of sedentary behavior, we were also interested in documenting the effect of the intervention program on light physical activity, moderate-to-vigorous physical activity, and health-related quality of life in older females.

Mean daily sedentary time for all participants at baseline was 5.70 $\pm$ 1.69 hours, a value which is noticeably lower than the average amount of time spent in sedentary behaviors (9.2 to 9.4 hours) reported by Buman et al. (2010) and Gennuso and colleagues (2013) in men and women 65 years of age and older. In these studies, values for daily sedentary time were obtained by accumulating 1-minute bouts containing less than 100 counts per minute, while daily sedentary time in our study was calculated by accumulating bouts of sedentary activity lasting at least 10 consecutive minutes, an approach consistent with the notion that shorter periods of sedentary behavior may be less strongly associated with negative health outcomes (Kim & Kang, 2013). If a 1-minute criterion for determining sedentary time had been employed in the current study, daily sedentary time would have risen to 8.9 hours, a value similar to that reported by other researchers (Buman et al., 2010; Gennuso et al., 2013) and 56% higher than the sedentary time value computed from using 10-minute criterion bouts of sedentary behavior. Although speculative, it seems reasonable to suggest that the selection of different criterion bout lengths of sedentary activity would likely have yielded different values for daily sedentary time which, in turn, might have altered the statistical outcomes of our study. The lack of standardization which currently exists regarding determination of sedentary time highlights the need to establish guidelines and protocols to evaluate various descriptors of physical inactivity so that findings from researchers, clinicians, and community-based practitioners can be easily compared and interpreted. Additionally, the relative lack of access to advanced motion sensors such as the activPAL, which can record body motion in multiple planes and differentiate among different postural positions, may have led to the misclassification of physical activities involving a static upright posture (i.e., standing) as sedentary activity rather than light-intensity activity and further hindered our ability to accurately quantify the effect of the activity intervention on sedentary behavior measures.

Despite our best efforts to deliver a month-long intervention program that was personally tailored to meet the needs and lifestyle preferences of our older female participants, we were unsuccessful in positively modifying sedentary behaviors and light-intensity physical activity. In contrast, two recent studies (Gardiner et al.,2011; Kozey-Keadle et al., 2012) reported decreases in free-living sedentary activity and an increase in the number of sedentary breaks in younger and older adults following 1- and 7-day counseling programs employing information-based strategies and behavior modification techniques to increase light-intensity activity. One possible interpretation from this set of findings is that it may be relatively easy to make short-term positive changes in reducing sedentary behavior, but much more challenging to sustain these behavioral changes in older adults, many of whom display functional limitations and diverse physical profiles (Brawley et al., 2003). Given that older adults display unique methods of social communication (Brawley et al., 2003), the promotion of active living in this demographic group using collaborative, social problem-solving models of behavior change that feature interaction with peers, family members, and neighbors should be explored. While the collection of weekly or biweekly data would help to better define the nature of changes in sedentary lifestyle outcomes during implementation of behavioral change programs, a longer intervention period may be required for older adults to establish and solidify behavioral change strategies to reduce and eliminate prolonged episodes of sedentary activity. Additionally, research and community-based efforts should also be directed towards documenting the separate and interactive effects of the built environment, level of disability, and physical function in promoting physical activity in older women and men.

Another potential reason for the lack of change in sedentary behaviors may be related to the level of moderate-to-vigorous physical activity (MVPA) we recorded in our sample. Baseline data from our study revealed that the average amount of daily MVPA was 37 minutes, a value which exceeds national physical activity guidelines of 30 minutes per day of MVPA (U.S. Department of Health & Human Services, 2008). Hence, when viewed collectively, our group of older females may have felt less of a need to increase levels of light-intensity physical activity. In light of this situation, future studies should emphasize the recruitment of adequately-sized samples of older women who display elevated levels of sedentary behavior, lower IADL scores, and lower MVPA levels.

The light-intensity activity intervention did not produce a significant increase in the frequency of breaks in daily sedentary time. Our findings differ from those of Gardiner and colleagues (2011), who demonstrated a 4% increase in the number of sedentary breaks per day and a 3.2% reduction in daily sedentary time in 59 older adults who participated in a 1-day intervention session to reduce and interrupt periods of sedentary time. At baseline, the average number of daily sedentary breaks in the Gardner study (2011) was 87.8, a value nearly identical to the mean number of pre-intervention daily sedentary breaks (86.0) calculated for all participants (G1, G2, G3) in the present investigation. This level of agreement is not surprising, as both studies used the same definition of a “sedentary break” (i.e., an interruption in sedentary time consisting of greater than 100 activity counts per minute and lasting one minute or longer). While it is unclear why the number of sedentary breaks did not increase following our 4-week activity intervention, our results parallel the absence of change in daily sedentary time we recorded for participants in both experimental groups.

A significant group by time interaction was noted for time spent in MVPA. While members of the control group displayed a 35% drop in MVPA time, G1 participants, who were contacted by the primary investigator once a week for 20 minutes during the last three weeks of the intervention, exhibited a 21% increase ($p < .05$) in MVPA time, whereas G2 participants, who were contacted by the lead investigator twice a week for 10 minutes during the same time period, displayed a 9% reduction in MVPA time. What is particularly curious about this finding is that an intervention designed solely for the purpose of increasing light-intensity physical activity produced a relatively large and statistically significant improvement in time spent in MVPA. Scrutiny of individual data collected on G1 participants revealed a consistent response across subjects, as seven out of eight participants exhibited post-intervention gains in MVPA. Moreover, while members of CON, G1, and G2 displayed mean reductions in light-intensity physical activity from pre- to post-intervention, the decrease in light-intensity activity for participants in G1 over the same time period was just over 5%, a relative change that was much lower in magnitude than decreases of over 10% and nearly 17% for G2 and CON participants, respectively. When actual directional changes in MVPA and light-intensity physical activity were summed, only participants in G1 displayed a net gain (~ 15%) in total physical activity level.

Based on guidelines published by the U.S. Preventive Services Task Force (2012), the intensity of behavioral counseling in the present investigation was considered medium (i.e., three to 24 contacts via telephone or 1 to 8 in-person sessions), and recent data suggest that physical activity counseling trials performed at medium- to-high-intensity can lead to greater self-reported physical activity (U.S. Preventive Services Task Force, 2012). Because the implementation of our medium-intensity behavioral intervention was accompanied by personalized feedback and reinforcement that was supplied on a weekly basis, the general lack of change in sedentary behaviors and physical activity displayed by participants in both experimental groups was disappointing. Given the increase in MVPA and total physical activity (light-activity + MVPA) time demonstrated by participants who were contacted by the primary investigator once a week for 20 minutes, we speculate that a longer contact session may have enabled G1 participants to better comprehend and internalize program content and the positive lifestyle messages conveyed by program staff compared to receiving two shorter (10-minute) periods of behavioral counseling separated by a 3-day span. Because little is known regarding the number, length, and nature of patient contacts required to produce sustained behavioral changes, it is recommended that community-based programs be undertaken to determine the proper composition and mix of program content, intensity and duration of behavioral counseling, and participant support needed to reduce sedentary behaviors and increase physical activity in older adults.

An important goal of this study was to quantify the extent to which sedentary behavior and physical activity levels measured immediately following the intervention were maintained over the next four weeks. Unfortunately, no interaction between group and time was present for any measure of sedentary behavior and physical activity during the retention phase of this project. Figures 1, 2, 3, and 4 display values for daily sedentary time, frequency of breaks in daily sedentary time, light-intensity physical activity, and moderate-to-vigorous physical activity measured (a) prior to the start of the intervention (T1); (b) at the end of the intervention (T2); and (c) at the end of the maintenance phase (T3). While fully acknowledging the lack of statistical change in a majority of the sedentary behavior and physical activity variables, visual inspection of data trends for G1 (contact once a week for 20 minutes) and G2 (contact twice a week; 10 minutes per session) revealed a generally stable response for daily sedentary breaks and light-intensity physical activity across all three time periods (Figures 1 and 2), whereas a more discordant response was observed for daily sedentary time and MVPA (Figures 3 and 4). Data presented in Figure 3, for example, indicated a 9% decrease in sedentary time during the intervention phase for G1, followed by a 4% increase towards pre-intervention values by the end of the retention period. In contrast, G2 participants exhibited less than a 2% reduction in daily sedentary time following the activity intervention, but displayed almost an 11% decrease in sedentary time during the maintenance phase. Another example of a divergent response pattern is evident in Figure 4, which depicts a change in MVPA of only 3% from the beginning of intervention until the end of the retention period for G1. However, for G2, MVPA fell by 9% after the training phase ended, but increased by nearly 43% during the retention period. Given the paucity of information which currently exists regarding the use of the behavioral change model to reduce sedentary behavior in older adults, further research is needed to develop effective approaches, with perhaps longer intervention and retention periods, to help older individuals decrease sedentary behavior, become more active, and maintain positive lifestyle changes (Marcus et al., 2000; Owen, Healy, Matthews, & Dustan, 2010; Sevick et al., 2007).

While the main emphasis of our study was to quantify the effects of a light-intensity physical activity intervention on sedentary behavior in community-dwelling older women, we were also interested in assessing the impact of this intervention approach on health-related quality of life (HRQOL) and instrumental activities of daily living (IADL). Although a significant group by time interaction was not present for HRQOL, a significant positive relationship (r = .44) was observed between the amount of reduction in daily sedentary time and improvements in HRQOL. This finding is consistent with results from a recent longitudinal investigation conducted by Balboa-Castillo et al. (2011) indicating that less leisure-time sedentary behavior (i.e., replacing one hour a day spent sitting with one hour a day of light-intensity physical activity) was independently associated with better long-term HRQOL in nearly 1100 men and women aged 62 years and older. These authors also confirmed that this relationship was statistically significant and clinically relevant for nearly all subscales (e.g., physical functioning, physical role, bodily pain, vitality, social functioning, and emotional role) of physical and mental health as measured by the 36-Item Short Form Health Survey (SF-36). Conversely, no significant association was observed in this study between the amount of reduction in daily sedentary time and change in IADL scores. A likely explanation for this finding is that a 'ceiling effect' may have existed for IADL scores, which were 7.81 $\pm$ 0.51 (pre-intervention) and 7.95 $\pm$ 0.22 (post-intervention) for all groups combined. As scores for this functional scale range from '0' (low function, dependent) to '8' (high function, independent), the opportunity for IADL scores to markedly improve in our group of older women was essentially non-existent.

Although the effectiveness of the behavioral modification program was limited, a number of subjects provided positive feedback regarding perceived benefits of participating in our study. General themes which appear to emerge from these comments include greater awareness of sedentary behavior, better physical well-being, and increased self-confidence. Below is a sampling of comments from our participants:

"Participating in this study increased my awareness on how much sitting I was doing, and every time I sat for a long period of time, I would remind myself to stand up and go do housework."

"I found a way to give myself a prompt while I am working on my computer by setting a timer that would go off in half an hour. It really helped me feel more energized when I made myself get up more."

"Getting up more often actually helped me decrease joint pain and stiffness."

"The focus of this study was to reduce sedentary behavior by replacing them with light-intensity activities, which were much more feasible for me. Every time I would try to increase my exercise level, it would not last long. Because all I need to do is not sit for a long period time, now I feel like I can make progress."

Conclusion

Findings from this feasibility study revealed that a 4-week behavioral intervention designed to increase light-intensity physical activity was unsuccessful in reducing daily sedentary time or decreasing the frequency of breaks in daily sedentary time in older, non-working females. While light-intensity activity remained unchanged, moderate-to-vigorous physical activity was increased among participants who received a single, weekly 20-minute period of individually-tailored feedback and support. Overall, there was no evidence that changes in sedentary behaviors and physical activity levels were maintained over the short-term following the intervention. However, a significant association was observed between reductions in daily sedentary time and improvement in health-related quality of life. To better gauge the efficacy of behavioral approaches to reduce sedentary activity in older women, it is recommended that future studies utilize motion sensor devices which function as inclinometers and be adequately powered with a larger sample size so that dose-response interactions among the intensity, frequency, and duration of participant contact, program content and delivery, and feedback and reinforcement strategies and their effect on retention of behavior changes and health outcomes can be examined.

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CHAPTER IV Appendices

Appendix A

Demographic and Health Questionnaire: CHAPTER IV

Demographic Questionnaire (Study 2)

Official use

Participant ID:		Today's Date:	
Height (cm):	_______________ _______________	(avg.) _________________	
Weight (kg):	_______________ _______________	(avg.) _________________	

Please complete Parts I and II.

Part I: Your background

DOB: _________ / _________ / _________

Age (years): __________

Sex: ___________

Race/ethnicity (circle one):

- Asian/Pacific Islander
- Arabic
- Black/African-American
- Latino/Latina
- Native American
- White/Caucasian
- Other (please specify), ________________

Highest education you have completed (circle one):

- Middle school
- High school
- College/University
- Graduate School
- Other (please specify), ________________

Are you currently employed (circle one)? Yes No

If "Yes," are you working for pay or as a volunteer (circle one)?

For pay As a volunteer

Please briefly describe your job, ____

Which best describes your annual family income?

- Less than $5,000
- Between $5,000 to $11,999
- Between $12,000 to $15,999
- Between $16,000 to $24,999
- Between $25,000 to $34,999
- Between $35,000 to $49,999
- Between $50,000 to $74,999
- $75,000 or more
- Don't know
- No answer

You are: Married
Never married
Divorced and remarried
Separated/Divorced
Widowed
In a relationship
Other (please specify), ________________________

Part II: Medical history & Dietary questions

Have you reached your menopause (circle one)? Yes No
If "Yes," age at menopause: _____

Age at menarche (years): _____

Number of births: _____

Age of first pregnancy: _____ Age of last pregnancy: _____

Breast feeding period (years): _____

Current use of **osteoporosis treatment medication** (circle one): Yes No
If "Yes," name(s) of medications (circle): Actonel (bisphosphonate)
Fosamax (bisphosphonate)
Didronel (bisphosphonate)
Evista (SERMs)
Forteo (PTH)
Protos (new)
Boniva (new)
Miacalcin (calcitonin)
Reclast (injection)
Other: _______________________

How many years have you been on **osteoporosis treatment medication**? __________ years

Are you on any **hormone replacement therapy (estrogen)**? Yes No

How many years have you been on hormone replacement therapy? _________ years

Chronic disease (circle one): diabetes mellitus
thyroid disease
hypertension
osteoarthritis
other forms of arthritis

Any additional medications: ____

Do you smoke cigarettes? (circle one) Yes No
If "No," do you have a history of smoking? Yes No
If "Yes," who long ago did you quit? _________ year ago

Have you ever had a bariatric surgery? Yes No

If "Yes," what year did you have it? _______

Number of falls in the past 12 months: _______

Have you ever broken a bone due to a simple fall? Yes No

If "Yes," when? Year ______ and body part(s) ___________________________

Are there female family member(s) with known or suspected poor bone health such as osteoporosis or osteopenia? Yes No

Have you ever had carbonated drinks during childhood? Yes No

Do you currently drink carbonated drinks? Yes No

Which of the following do you currently consume? (circle all that apply)

Supplements:
Calcium
Vitamin D
Calcium + vitamin D
Multivitamin
Vitamin K
Protein
Others:
Alcohol
Caffeine

Which of the following did you consume in the past? (circle all that apply)

Supplements:
Calcium
Vitamin D
Calcium + vitamin D
Multivitamin
Vitamin K
Protein
Others:
Alcohol
Caffeine

Investigator will interview you to complete the following -

Part III: Behavioral questions

Overall sedentary time.

The following question is about **sitting or reclining** at home, at work, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading or watching televisions], but do not include time spent sleeping.

How much time do you usually spend sitting or reclining on a typical day?

______ hours and ______ minutes per day

Current physical activity.
Following questions will ask you about the time you *currently* spend in physical activities including **light activities** [activities of daily living], **aerobic activities** [such as walking, dancing, swimming, aerobic exercise classes, bicycle riding, gardening, tennis, and/or golf] and **muscle-strengthening activities** [such as exercises with bands, weight machines, free weights, push-ups, lifting, carrying, yoga and/or Tai chi exercises].

On a typical day, how much time do you usually spend time in light activities [such as light housework]?

______ hours and ______ minutes per day

On a typical day, how much time do you usually spend time in activities that require **medium level of effort**? On a scale of 0 to 10, where sitting is 0 and the greatest effort possible is 10, medium level of effort is a **5 or 6** that produces increased breathing rate and heart rate.

______ hours and ______ minutes per day

On a typical day, how much time do you usually spend time in activities that require **high level of effort**? On the same scale as above, high level of effort is a 7 or 8 that produces large increases in breathing rate and heart rate.

______ hours and ______ minutes per day

During a typical week, how many days do you spend time in **muscle-strengthening activities** that involve all of the major muscle groups [such as the muscles of the legs, hips, chest, back, abdomen, shoulders, and arms]?

______ days per week

Appendix B

Assessment Tool of Instrumental Activities of Daily Living: CHAPTER IV

The Lawton Instrumental Activities of Daily Living Scale

Ability to Use Telephone

1. Operates telephone on own initiative; looks up and dials numbers... 1
2. Dials a few well-known numbers............................... 1
3. Answers telephone, but does not dial......................... 1
4. Does not use telephone at all..................................... 0

Shopping

1. Takes care of all shopping needs independently 1
2. Shops independently for small purchases................. 0
3. Needs to be accompanied on any shopping trip 0
4. Completely unable to shop 0

Food Preparation

1. Plans, prepares, and serves adequate meals independently 1
2. Prepares adequate meals if supplied with ingredients... 0
3. Heats and serves prepared meals or prepares meals but does not maintain adequate diet......................... 0
4. Needs to have meals prepared and served................. 0

Housekeeping

1. Maintains house alone with occasion assistance (heavy work).. 1
2. Performs light daily tasks such as dishwashing, bed making.. 1
3. Performs light daily tasks, but cannot maintain acceptable level of cleanliness 1
4. Needs help with all home maintenance tasks........... 1
5. Does not participate in any housekeeping tasks........ 0

Laundry

1. Does personal laundry completely 1
2. Launders small items, rinses socks, stockings, etc........ 1
3. All laundry must be done by others 0

Mode of Transportation

1. Travels independently on public transportation or drives own car... 1
2. Arranges own travel via taxi, but does not otherwise use public transportation 1
3. Travels on public transportation when assisted or accompanied by another 1
4. Travel limited to taxi or automobile with assistance of another... 0
5. Does not travel at all 0

Responsibility for Own Medications

1. Is responsible for taking medication in correct dosages at correct time... 1
2. Takes responsibility if medication is prepared in advance in separate dosages 0
3. Is not capable of dispensing own medication 0

Ability to Handle Finances

1. Manages financial matters independently (budgets, writes checks, pays rent and bills, goes to bank); collects and keeps track of income............................ 1
2. Manages day-to-day purchases, but needs help with banking, major purchases, etc 1
3. Incapable of handling money 0

Scoring: For each category, circle the item description that most closely resembles the client's highest functional level (either 0 or 1).

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Appendix C

Assessment Tool of Health-Related Quality of Life: CHAPTER IV

Medical Outcomes Study: 36-Item Short Form Survey Instrument RAND 36-Item Health Survey 1.0 Questionnaire Items

1. In general, would you say your health is:	
Excellent	1
Very good	2
Good	3
Fair	4
Poor	5

2. Compared to one year ago, how would your rate your health in general now?	
Much better now than one year ago	1
Somewhat better now than one year ago	2
About the same	3
Somewhat worse now than one year ago	4
Much worse now than one year ago	5

The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?
(Circle One Number on Each Line)

	Yes, Limited a Lot	Yes, Limited a Little	No, Not limited at All
3. Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports	[1]	[2]	[3]
4. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	[1]	[2]	[3]
5. Lifting or carrying groceries	[1]	[2]	[3]
6. Climbing several flights of stairs	[1]	[2]	[3]

7. Climbing one flight of stairs	[1]	[2]	[3]
8. Bending, kneeling, or stooping	[1]	[2]	[3]
9. Walking more than a mile	[1]	[2]	[3]
10. Walking several blocks	[1]	[2]	[3]
11. Walking one block	[1]	[2]	[3]
12. Bathing or dressing yourself	[1]	[2]	[3]

During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?
(Circle One Number on Each Line)

	Yes	No
13. Cut down the amount of time you spent on work or other activities	1	2
14. Accomplished less than you would like	1	2
15. Were limited in the kind of work or other activities	1	2
16. Had difficulty performing the work or other activities (for example, it took extra effort)	1	2

During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?
(Circle One Number on Each Line)

	Yes	No
17. Cut down the amount of time you spent on work or other activities	1	2
18. Accomplished less than you would like	1	2
19. Didn't do work or other activities as carefully as usual	1	2

20. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups? (Circle One Number)
Not at all 1
Slightly 2
Moderately 3
Quite a bit 4
Extremely 5

21. How much bodily pain have you had during the past 4 weeks?
(Circle One Number)
None 1
Very mild 2
Mild 3
Moderate 4
Severe 5
Very severe 6

22. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?
(Circle One Number)
Not at all 1
A little bit 2
Moderately 3
Quite a bit 4
Extremely 5

These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling.
How much of the time during the past 4 weeks . . .
(Circle One Number on Each Line)

	All of the Time	Most of the Time	A Good Bit of the Time	Some of the Time	A Little of the Time	None of the Time
23. Did you feel full of pep?	1	2	3	4	5	6
24. Have you been a very nervous person?	1	2	3	4	5	6
25. Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
26. Have you felt calm and peaceful?	1	2	3	4	5	6
27. Did you have a lot of energy?	1	2	3	4	5	6
28. Have you felt downhearted and blue?	1	2	3	4	5	6

29. Did you feel worn out?	1	2	3	4	5	6
30. Have you been a happy person?	1	2	3	4	5	6
31. Did you feel tired?	1	2	3	4	5	6

32. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?
(Circle One Number)
All of the time 1
Most of the time 2
Some of the time 3
A little of the time 4
None of the time 5

How TRUE or FALSE is each of the following statements for you.
(Circle One Number on Each Line)

	Definitely True	Mostly True	Don't Know	Mostly False	Definitely False
33. I seem to get sick a little easier than other people	1	2	3	4	5
34. I am as healthy as anybody I know	1	2	3	4	5
35. I expect my health to get worse	1	2	3	4	5
36. My health is excellent	1	2	3	4	5

Appendix D

Sedentary Behavior Record for Adults (SBR-A): CHAPTER IV

Sedentary Behavior Record for Adults (SBR-A)

Name: ______________________________ Day: 1 2 3 4 5 6 7 (Circle one) Date: ________/________/________
month day year

Directions: Fill in each cell on the right table with the corresponding number that best fits the description of activity performed (see table below) during the 15 minute period. If the cell corresponds with a time that was not listed below, leave the cell blank or cross-out the cell(s).

Number	Sedentary Behavior
1	Sleep
2	Lying down for screen time: computer use, television, electronic gaming, kindle, etc…
3	Lying down: anything other than screen time and with the expectation of sleeping
Non-Work Related Sitting	
4	Transit that requires sitting (other than biking)
5	Screen time: computer use, television viewing, electronic gaming, kindle, etc…
6	Other: eating, reading, socializing, etc.
Work Related Sitting	
7	Transit to/from work as well as job-related driving that requires sitting (other than biking)
8	Screen time: computer use or other electronic device
9	Other: eating, reading, socializing, etc.

Start Time: _____ am / pm
End Time: _____ am / pm
Off time: _______~_______

Hour	Minutes			
	0-15	16-30	31-45	46-60
midnight-1:00				
1:00-2:00				
2:00-3:00				
3:00-4:00				
4:00-5:00				
5:00-6:00				
6:00-7:00				
7:00-8:00				
8:00-9:00				
9:00-10:00				
10:00-11:00				
11:00- noon				
Noon -1:00pm				
1:00-2:00pm				
2:00-3:00pm				
3:00-4:00pm				
4:00-5:00pm				
5:00-6:00pm				
6:00-7:00pm				
7:00-8:00pm				
8:00-9:00pm				
9:00-10:00pm				
10:00-11:00pm				
11:00-midnight				

CHAPTER V

PROJECT CONCLUSIONS

Emerging evidence indicates that sedentary behavior can negatively impact health outcomes (Dunstan, Barr, Hamer, & Dunstan, 2010; Ford, Kohl, Mokdad, & Ajani, 2005; Healy, Dunstan, Zderic, & Owen, 2008; Patel et al., 2010; Stamatakis, Hamer, & Dunstan, 2011; Tremblay et al., 2010) and physical inactivity appears to have a negative mediating effect on bone metabolism in humans (Tremblay et al., 2010). Because challenges remain in promoting exercise adherence and maintaining appropriate health-related levels of physical activity in the aging population (Brawley et al., 2003), it may be more feasible for older adults to focus on replacing sedentary behavior with less-intense physical activity which can be incorporated into their daily living routines (Garber et al., 2001). Against this backdrop, a series of three studies were performed to extend our understanding of the separate and interactive effects of physical activity and sedentary behavior on bone health in older women.

In the first study of this dissertation, publically-available surveillance data collected on more than 2,000 females aged 12 years and older were analyzed to quantify the relative contribution of self-report measures of sedentary behavior and physical activity to areal bone mineral density (aBMD) and bone mineral content (BMC) at the femoral and spinal regions. Results indicated that performing a minimum of 60 minutes per day of moderate-to-vigorous recreational physical activity was associated with increased aBMD and BMC at the femoral neck and lumbar spine in adolescent females.

Conversely, greater amounts of self-reported sedentary behavior were related to lower femoral neck aBMD and BMC levels in females 65 years of age and older.

Based on the differential effects of MVRPA and self-reported sedentary behavior on bone health reported in our first study, the focus of the second study of this dissertation was to determine if bone health status at the femoral and spinal regions could be accurately predicted from accelerometer-derived measures of sedentary activity and physical activity in 44 healthy, post-menopausal women. After adjustment for other variables in the model, logistic regression analysis demonstrated that sedentary time and frequency of breaks in daily sedentary time were significant and unique predictors of aBMD at the femoral neck. Of particular interest was the finding that a 1-unit increase in the frequency of breaks in daily sedentary time was associated with a 10% decrease in the odds of osteopenia and osteoporosis. In contrast, the degree of adherence to current health-related activity guidelines was not a significant predictor of femoral neck aBMD, and daily sedentary time, frequency of breaks in daily sedentary time, and level of adherence to recommended guidelines for physical activity were not significant contributors to lumbar spine bone health status.

The final study of this dissertation documented the effectiveness of a 4-week, personalized behavioral intervention aimed at replacing sedentary behaviors with weight-bearing, light-intensity physical activities in older, non-working females. A total of 24 volunteer participants were randomly assigned in equal numbers to a control group (CON) or two experimental groups (G1, G2) that received one weekly 20-minute contact (G1) or two 10-minute contacts each week (G2) with the primary investigator that focused on helping participants decrease sedentary behaviors and increase participation in light-intensity physical activities within the context of a multi-component behavioral change model. Data analyses from this feasibility study revealed no change in daily sedentary time, frequency of breaks in daily sedentary time, or light-intensity physical activity, but moderate-to-vigorous physical activity was significantly increased in G1 participants. In addition, reductions in daily sedentary time were positively and significantly related to improvements in health-related quality of life.

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PROJECT APPENDICES

Appendix A

Review of the Literature

Introduction

In this appendix, the relevant literature related to physical activity and bone health is reviewed. The appendix begins with a general overview of the epidemiology of osteoporosis and determinants of bone health and a discussion of bone physiology and bone metabolism, including the effects of mechanical loading on bone structure. Next, the role of exercise and physical activity on bone health parameters in youth and adults is examined and a description of the potential impact of reducing sedentary behavior on bone health in older women is presented. This section is followed by a discussion of the health-related impact of sedentary living and reducing sedentary behaviors and a description of behavioral change interventions and activities of daily living and their relationship to health and physical function. The appendix ends with an overall summary.

Epidemiology of Osteoporosis

Overview. Osteoporosis, a common bone disease characterized by low bone mass and structural deterioration of bone tissue, can result in skeletal fragility and increased susceptibility to fractures of the hip, spine, and wrist (Cummings & Melton, 2002; Ioannidis et al., 2009; Kanis, Johansson, Oden, & McCloskey, 2009; National Institute of Health, 2010). A major worldwide health issue (Ahlborg et al., 2010; Ho-Pham, Nguyen, Pham, Nguyen, & Nguyen, 2011; Johnell & Kanis, 2006), osteoporosis-related fracture (ORF) is associated with increased mortality and morbidity and inflicts a greater economic burden on the elderly (Ahlborg et al., 2010; Burge et al., 2007; Ioannidis et al., 2009).

As life expectancy continues to rise in the United States (Murphy, Xu, & Kochanek, 2012), the prevalence of osteoporosis is expected to increase from 10 million to more than 14 million people by 2020 (Burge et al., 2007). In addition, half of all Americans over the age of 50 display low bone mass levels (U.S. Department of Health and Human Services, 2004), which raises concerns of increased ORF and related health consequences in this segment of the population. In 2002, nearly 13,000 older adults in the United States died as a result of injuries resulting from falls and more than 1.5 million older adults were treated in emergency rooms, with approximately 390,000 being hospitalized (Stevens, Corso, Finkelstein, & Miller, 2006).

Despite the fact that one in two women and one in five men 50 years and older are expected to have an ORF in their lifetime, bone health is an oft-ignored component of overall health (U.S. Department of Health and Human Services, 2004). An observational study in which individuals aged 50 years and above were monitored for five years revealed that nearly all types of fractures (i.e., vertebral, hip, pelvic, and forearm/wrist) were more common in women than men (Ioannidis et al., 2009). Results from this study demonstrated that participants with hip or vertebral fractures were at greater risk of dying during the 5-year followup period compared to those without fractures (Ioannidis et al., 2009). In addition, women who experienced hip and vertebrae fractures in the first year of the study were 2.99 and 3.71 more likely to die, respectively, than those who did not sustain these types of fractures (Ioannidis et al., 2009). In considering women 65 years of age and older, an 8.3-year cohort investigation documenting the prevalence of vertebral fractures and mortality reported that females with one or more fractures displayed a 1.23-fold greater age-adjusted mortality rate compared to women with no indication of previous fractures (Kado et al., 1999). A relationship between vertebral fracture and mortality rate from pulmonary disease and cancer was also noted, such that women with vertebral fractures were more likely to die of lung cancer than those with no vertebral fractures, even after adjusting for current and past smoking habits (Kado et al., 1999). Moreover, women with severe vertebral fractures exhibited an adjusted 1.5-fold greater risk of dying from chronic obstructive pulmonary disease and pneumonia (Kado et al., 1999).

In terms of comorbidity, a strong association exists between non-fatal fractures and reductions in physical function and independence, leading to an increased demand on healthcare services (Stevens et al., 2006). The increased reliance on hospitalization associated with ORF results in greater financial costs for persons 65 years of age and older. In the year 2000, for instance, a total annual expenditure of 19 billion dollars was incurred from injuries caused by 2.6 million non-fatal falls, and the majority of this cost was attributable to fractures occurring in women (Burge et al., 2007; Stevens et al., 2006). Similarly, Burge and colleagues (2007) estimated that by 2025, the yearly fracture incidence and accompanying monetary costs will rise by 50%. These substantial monetary drains have led to a greater sense of urgency to develop effective strategies to prevent osteoporosis and ORF (Stevens et al., 2006).

Not only does comorbidity associated with ORF adversely impact older adults, but health-related quality of life (HRQOL) is also diminished in persons with vertebral fractures (Silverman, Minshall, Shen, Harper, & Xie, 2001). Due to a reduction in physical function linked to fractured vertebrae, clinical symptoms (i.e., pain and fatigue), and altered emotional status (i.e., fear of falling, level of tension, body image, and independence), overall HRQOL scores are substantially lower in postmenopausal women with ORF compared to those who have not experienced fractures (Silverman et al., 2001). Based on data showing that only one-third of total vertebral fractures are reported to health-care providers, and that back pain and impaired functional mobility contribute to a lower HRQOL (Silverman et al., 2001), it is vital to continue developing and testing the efficacy of various clinical and activity-based interventions to prevent fractures, especially among elderly women.

Determinants of bone health. Non-modifiable risk factors for bone health include age, sex, family history, and race/ethnicity (Ho-Pham et al., 2011; Kanis et al., 2009; NIH 2010). Age is an independent risk factor that influences bone mineral density (BMD), insofar as BMD decreases with age and fracture risk is much higher in older individuals compared to young adults (Kanis et al., 2009). Sex is another significant predictor of BMD, especially in adults who are 50 years of age and older. While the majority of total bone loss in the spinal region (i.e., trabecular bone) takes place before menopause, a drastic reduction in cortical bone mass (e.g., midradius) also starts after menopause and continues into older adulthood (Riggs et al., 1986). As estrogen levels fall during menopause (~ 50 years of age), there is a greater loss of bone in women and an accompanying susceptibility to osteoporosis and osteoporotic fractures (Looker, Melton, Harris, Borrud, & Shepherd, 2010). A family history of osteoporotic fractures, especially at the hip, is also a significant and independent predictor of low BMD (Kanis et al., 2009). In considering race and ethnicity and their role in bone loss, Caucasian and Asian females display a higher risk of osteoporosis compared to African-American and Hispanic females (Ho-Pham et al., 2011; NIH, 2010).

Modifiable risk factors associated with bone health include body mass index (BMI), smoking (Hollenbach, Barrett-Connor, Edelstein, & Holbrook, 1993), alcohol and medication use (Kanis et al., 2009; Looker et al., 2010), dietary intake (Soroko, Holbrook, Edelstein, & Barrett-Connor, 1994), dietary supplementation (Dawson-Hughes, Harris, Krall, & Dallal, 1997) and a sedentary lifestyle (Kanis & McCloskey, 1998). Considerable evidence exists that body mass index (BMI), calculated by dividing body mass (kilograms) by height (meters squared), is strongly related to BMD (Looker et al., 2010), such that leanness (i.e., lower BMI) increases the risk for hip fracture by a factor of two (Kanis et al., 2009). Use of alcohol and cigarette smoking also elevates bone fracture risk (Kanis et al., 2009). In considering the association between smoking and bone density, a dose-response relationship has been reported (Hollenbach et al (1993) indicating that men and women 60 years and older who smoked less than or equal to one pack of cigarettes a day exhibited a significantly lower hip BMD compared to individuals who had never smoked. Similarly, participants who smoked more than one pack of cigarettes on a daily basis displayed a significantly lower hip BMD than did those who smoked one pack or less a day (Hollenbach et al., 1993). With respect to medication use, BMD values can be positively or negatively influenced. Long-term glucocorticoid exposure, for instance, is a strong predictor of low BMD and is linked to a greater fracture risk (Kanis et al., 2009), whereas medications such as biphosphanates, calcitonin, calcitriol, parathyroid hormone, selective estrogen receptor mimics (SERMs), and sex hormones (estrogen or estrogen combine with progesterone) are often prescribed by healthcare professionals to increase BMD levels in older women (Kanis et al., 2009; Looker et al., 2010).

Measurement of osteoporosis. Widely-used bone health variables, such as areal bone mineral density (aBMD, defined as the amount of bone mineral in grams per square centimeter of bone area) and bone mineral content (BMC, or the amount bone mineral in grams per centimeter of bone), are most commonly determined using bone densitometry or dual-energy x-ray absorptiometry (DXA) (Kayalar et al., 2009; Kemper, 2009; Srinivasan et al., 2012). Considered the "gold standard" for non-invasive measurement of BMC and aBMD, DXA employs technology that differentiates bone mineral from soft tissue (i.e., a 2-compartment model) (Kayalar et al., 2009). With DXA, a low-dose x-ray beam at two different energy levels is absorbed by bone and non-bone (i.e., lean mass and fat mass) tissues and aBMD is determined when the absorption of the photon beam by soft tissues is subtracted out from the total x-ray absorption of the beam (Blake & Fogelman, 1997).

Bone strength has also been assessed using a dual-energy x-ray laser (DXL) which measures BMC based on a 3-component model (i.e., bone mineral, lean soft tissue, and fat mass) (Kayalar et al., 2009). The recent use of DXL technology to quantify bone density at the calcaneous has been applied in clinical practice as a preliminary screening tool to estimate fracture risk at the hip and lumbar spine (Kayalar et al., 2009). While DXA and DXL measure axial BMD, peripheral quantitative computed tomography (pQCT) assesses volumetric BMD, bone size, and bone strength, all of which are considered to be better predictors of fracture risk in men and women than bone strength indices provided by DXA (Srinivasan et al., 2012). While pQCT represents an advancement in bone imaging technology, the clinical relevance of pQCT remains questionable, given that pQCT scans are typically obtained at the distal radius and proximal tibia, sites which are less-common areas of ORF compared to the femoral neck and lumbar spine (Gunter, Almstedt, & Janz, 2012). Additionally, pQCT requires a higher dose of radiation compared to DXA (Gunter et al., 2012). Consequently, aBMD as measured by DXA is still routinely used to evaluate fracture risk at the hip and lumbar spine in adults (Ho-Pham et al., 2011; Kayalar et al., 2009; NIH, 2010) and especially among women who are 50 years of age and older (Gunter et al., 2012).

BMD values are usually expressed as a T-score, which is derived from an individual's aBMD score and a comparison of this score with the average peak bone mass of a healthy adult population based on standard deviation values (Kanis et al., 2000; Kanis et al., 2008; Ho-Pham et al., 2011). The World Health Organization (WHO) has established criteria for osteoporosis drawn from findings from the third National Health and Nutrition Examination Survey (NHANES III) administered between 1988 and 1994 (Kanis et al., 2000; Kanis et al., 2008) (see Tables 1 and 2). Using these data, osteoporosis is defined as a T-score greater than -2.5, meaning that the BMD value is more than 2.5 standard deviation values below the mean BMD value of healthy adults aged 20 to 29 years (Cummings, Bates, & Black, 2002; Kanis et al., 2000; Kanis et al., 2008; Looker et al., 2010). An absolute BMD cutoff value of 0.577 g/cm^2 for osteoporosis has been established using BMD values for women aged 20 to 29 years of age (Kanis et al., 2009; Kanis et al., 2000). Similarly, the WHO has set a T-score range of between -1.0 and -2.5 and an absolute criterion (i.e., 0.740 g/cm^2) for osteopenia, a condition in which bone density falls below the healthy range for young adults, but does not reach the criterion for osteoporosis (Cummings et al., 2002; Kanis et al., 2000; Kanis et al., 2008; Looker et al., 2010).

Because T-scores compare individual BMD values to mean BMD measures obtained on healthy young adults, the use of T-scores is not appropriate when evaluating the bone health of children and adolescents undergoing growth and development (Horlick, Wang, Pierson, & Thornton, 2004; Specker & Schoenau, 2005). Though caution is warranted when interpreting DXA scans for maturing children due to the inherent challenges of using 2-dimensional measurements to predict 3-dimensional structures (Horlick et al., 2004), the use of Z-scores to compare individual BMD values to values measured on age- and sex-matched reference groups is an acceptable method of assessing bone mass status in healthy children (Cummings et al., 2002; Leib, Lweiecki, Binkley, & Hamdy, 2004; Specker & Schoenau, 2005). Using this approach, a Z-score of -1.0 would indicate that the BMD value for a child or adolescent at a specific anatomical site is one standard deviation below the mean BMD value of an age- and sex-matched reference group (Cummings et al., 2002). In youth, the diagnosis of osteoporosis cannot be made based on Z-scores alone (Binkovitz & Henwood, 2007), and the appropriate terminology for this medical condition is “low bone density for chronological age” when the z-score value is -2.0 or lower (Leib et al., 2004).

The two primary DXA manufacturers in the United States, Hologic (Hologic, Inc., Bedford, MA) and Lunar (GE, Madison, WI), measure bone density at various skeletal sites (Carey et al., 2007). Although DXA is considered the “gold standard” for non-invasive measurement of aBMD (Hamdy, Petak, & Lenchik, 2002), it is important to note that T-and Z-score calculations vary across manufacturers, resulting in noticeably different values for a given aBMD value (Carey et al., 2007). For example, the Hologic DXA machine adjusts for ethnicity when computing T-scores, while the Lunar instrument does not account for this factor. Conversely, while Hologic software does not adjust for weight when calculating z-scores, Lunar software accounts for this variable. Given these methodological differences across DXA manufacturers, caution should be applied when interpreting DXA-derived bone scores in young adult (Carey et al, 2007) and pediatric populations (Binkovitz & Henwood, 2007). Furthermore, standardization of z-score definitions and calculations is recommended to improve the reliability of DXA-generated bone parameters (Carey et al., 2007).

Assessment of fracture risk. As noted earlier, WHO has established a criterion measure (i.e., T-score < -2.5) for osteoporosis based on NHANES III bone measures obtained at the proximal femur using DXA (Kanis et al., 2009; Kanis et al., 2000; Melton, 1997). A BMD value of less than -2.5 significantly increases osteoporotic fracture risk in women aged 65 years and older and in men aged 70 years and older (Leib et al., 2004). With regard to assessing bone density at specific skeletal sites, it has been suggested that the lumbar spine (vertebrae L1-L4) and hip be evaluated in postmenopausal women (Hamdy et al., 2002) and that the lowest T-score across regions of interest (i.e., lumbar spine, femoral neck, total hip, and greater trochanter) be used in the diagnosis of osteoporosis (Hamdy et al., 2002; Leib et al., 2004). In situations where measurements at the lumbar spine or hip cannot be interpreted reliably (e.g., hyperparathyroidism), distal radius aBMD should be measured. In the pediatric population, it is recommended that density of the lumbar spine and total body be quantified when determining bone health status. Moreover, further research is needed to reach consensus on how best to adjust BMC and aBMD values for pubertal status, skeletal maturation, and body composition in children and adolescents (Leib et al., 2004).

While DXA measurement of bone density at the hip is a strong predictor of fracture risk in older adults, assessment of supplemental clinical risk factors (e.g., BMI, previous fracture history, family history of osteoporosis, smoking, alcohol use, medication use) should be performed to estimate fracture risk in men and women (Kanis et al., 2009). When accompanied by secondary causes of decreased bone density (e.g., long-term glucocorticoid therapy, hypogonadism, and hyperparathyroidism), low aBMD values may also aid in predicting fracture risk in women between the age of 20 years and menopause (Leib et al., 2004). Lastly, a T-score of less than -2.5 may not be an appropriate criterion for osteoporosis among persons of different ethnic and racial backgrounds when determining fracture risk (Melton, 1997). Some researchers, for example, have argued that treatment of osteoporosis in 60- to 70-year-old women of Caucasian and Asian ethnicity should commence when T-score values fall below -2.0 (Nguyen, Ahlborg, Center, Eisman, & Nguyen, 2007).

Fall prevention and osteoporosis-related fractures. Each year, more than one in three people aged 60 years and older experience falls and fall-related injuries (NIH Senior Health, 2011) and the financial consequences of falls in older adults are substantial (Stevens et al., 2006). In 2005, it was estimated that more than two million fractures in the United States led to direct medical costs of $17 billion (Burge et al., 2007; Kuehn, 2005) and associated monetary costs are predicted to increase 50% by 2025 (Burge et al., 2007). Among fractures occurring due to falls, hip fractures are considered the most serious type of fracture, as they are associated with disability and loss of independence (e.g., being discharged to nursing facilities after fall-related injury) (Alexander, Frederick, & Wolf, 1992; Rubenstein, 2006).

For a given T-score, the probability of femoral neck fracture increases with age. For example, if the T-score is -3.0, a 70-year-old female will exhibit a much higher probability of fracture compared to a 50-year-old female (Kanis et al., 2009). Hence, fall prevention becomes exceedingly important for older adults (i.e., 65 years and above) and those who are at risk for low bone mass. Based on observations from multiple clinical controlled trials, researchers have identified eight risk factors for falls in older persons; these include muscle weakness, balance deficit, mobility limitation, impaired functional status, gait deficit, visual deficit, cognitive impairment, and postural hypotension (Rubenstein, 2006). Reviews and meta-analyses have demonstrated that along with environmental assessment and modification, intervention strategies aimed at improving balance, muscular strength, and muscular endurance can be effective in preventing falls in elderly persons (≥ 65 years of age), especially at the hip and wrist (Chang et al., 2004; Kannus et al., 2005; Rubenstein, 2006).

Due to the reduced health and fitness status of older adults, the ability to perform activities of daily living is compromised to some extent (Bowling & Grundy, 1997). Hence, current thought in preventing falls is to encourage older adults to participate in a multifaceted program featuring increases in daily living activities (i.e., light-intensity activities such as standing and walking) related to functional performance. From a research perspective, relatively little is known concerning the effect of increasing light-intensity activities of daily living on bone health and osteoporosis risk in elderly women (Chang et al., 2004).

Physiology of osteoporosis

Introduction. Bone is a dynamic tissue that undergoes constant breakdown (i.e., bone resorption or osteoclastic activity) and replacement (i.e., bone formation or osteoblastic activity) (NIH, 2010; Raisz, 1999; Robling, Castillo, & Turner, 2006; Watts, 1999). The remodeling cycle of bone begins with osteoclastic resorption which produces irregular cavities on trabecular bone, followed by a reversal phase in which growth factors are released to stimulate bone creation. During bone formation, cavities formed by osteoclastic activity are filled in with layers of osteoblasts, or cells which deposit bone mineral (Raisz, 1999). The process of bone remodeling illustrates that bone is capable of “self-repair” (Robling et al., 2006), and this cycle of bone turnover creates a healthy and strong skeletal structure (Frost, 1989). However, in cases where osteoclastic activity overrides osteoblastic activity, bone mass decreases and bone fragility increases, which can eventually lead to osteoporosis. Trabecular bone is less dense compared to cortical bone, which has a smooth, compact surface. As such, skeletal sites which consist of relatively larger portions of trabecular bone (e.g., femoral neck, lumbar spine, and wrist) are common sites of osteoporosis.

Peak bone mass. During childhood and adolescence, the process of bone remodeling favors bone formation over bone breakdown and leads to an increase in bone density until peak bone mass is maximized (Lebrun, 2006; NIH, 2010). During skeletal development, the outer layer of the bone (cortical bone) is formed and with trabecular bone filling up the inner layer of the bone, the integrity and density of the bone increases (Frost, 1989; Lebrun, 2006). In women, the majority of peak bone mass is attained prior to 20 years of age and remains fairly constant until about 50 years of age, after which peak bone mass starts to decline at a rate which increases once menopause begins (Kanis et al., 2008; Lebrun, 2006; NIH, 2010). Although 75% of peak bone mass levels can be attributed to sex and ethnicity, 25% of peak bone mass is accounted for by environmental factors such as nutrition, physical activity, and lifestyle behaviors (McDevitt & Ahmed, 2009; NIH, 2010). Recent reviews have emphasized the importance of optimizing peak bone mass during growth and maturation (Karlsson, Nordqvist, & Karlsson, 2008; Gunter et al., 2012; MacKelvie, Khan, & McKay, 2002; Ondrak & Morgan, 2007; Rizzoli, Bianchi, Garabedian, McKay, & Moreno, 2010) as a means of lowering the risk of osteoporosis later in life.

Regulation of bone metabolism. Typical biomarkers of bone metabolism include serum bone-specific alkaline phosphatase and osteocalcin, two biochemical indices of bone anabolism. In an 8-month clinical trial aimed at improving BMD at the hip and lumbar spine in older females (Jessup, Horne, Vishe, & Wheeler, 2003), participants wore weighted vests three times a week (20 to 30 minutes per session) while performing walking, stair climbing, and balancing activities. Findings from this investigation revealed a significant increase in BMD at the femoral neck that was linked to increases in osteocalcin and bone-specific alkaline phosphatase. In contrast with results of Jessup and colleagues (2003), a study of older women (Humphries et al., 2000) comparing the impact of a high-intensity resistance training program and a low-intensity walking program (both lasting six months) found no significant change in BMD following both modes of training. In the report by Humphries and associates, it was speculated that the lack of change in BMD in both exercise groups may have been related to the natural pattern of bone adaptation, wherein BMD initially decreases in response to resistance training before an increase is observed. Finding from the Humphries et al. study (2000) suggest that six months of low-intensity walking or high-intensity resistance training may not be long enough to produce improvements in BMD values in older women. In addition, while walking led to significantly higher osteocalcin levels, lumbar spine BMD actually decreased below the baseline measure. While these findings seem puzzling, recent studies have indicated osteocalcin as a significant metabolic hormone, in which regulation of insulin secretion, energy expenditure, and insulin resistance are positively influenced by increased secretion of osteocalcin (Ducy, 2011). Osteocalcin is also known for indirectly enhancing bone resorption (Ducy, 2011). Although speculative, the walking intervention may have enhanced osteoblastic activity which in response, may have caused osteoclastic activity to exceed osteoblastic activity, resulting in bone loss. To counteract this possibility, the use of hormone therapy has become a common and effective supplemental treatment to reduce bone turnover rate in older women (Humphries et al., 2000). In the past decade, however, hormone replacement therapy use has decreased as it is linked to an increased risk of developing breast cancer in postemenopausal women (Reeves et al., 2006).

Mechanical loading and bone remodeling. The influence of mechanical stimuli on bone health has been well-documented by interventions aimed at increasing mechanical loading on bone (Kohrt, Bloomfield, Little, Nelson, & Yingling, 2004; Morseth, Emaus, & Jorgensen, 2011). As noted earlier, bone is a dynamic tissue that is constantly engaged in a remodeling process (Raisz, 1999; Robling et al., 2006) featuring bone removal and the production of new bone. This turnover activity occurs mainly in trabecular bone, which is responsive to mechanical loading (Moresth, Emaus, & Jorgensen, 2011).

During muscle contraction, gravitational/ground-reaction forces and muscle-joint forces are generated which produce mechanical loading of bone tissue (Kohrt et al., 2004; Morseth et al., 2011). The largest osteogenic effect associated with physical loading at the femoral neck is produced by high-intensity weight-bearing activity involving a limited number of loading cycles imposed on a daily or weekly basis. Resistance training has also been shown to be the most effective method of increasing bone mass at the lumbar spine (Kohrt et al., 2004; Morseth et al., 2011). In addition, data from animal studies have demonstrated that short bouts of high-impact bone loading that are separated into multiple sessions within a day lead to optimal bone formation in rats (Turner & Robling, 2003). From these reports, it has been suggested that rest and recovery periods are needed after a given number of loading cycles to restore the sensitivity of the bone tissue to loading (Kohrt et al., 2004). In fact, results from another animal study suggest that more frequent short bouts of daily exercise may actually be more osteogenic than a single, prolonged exercise session (Robling, Hinant, Burr, & Turner, 2002). Although more research is necessary to identify the optimal interaction among intensity, duration, and frequency of exercise to maximize bone mass in humans of all ages (Kohrt et al., 2004; Morseth et al., 2011), limited findings suggest that shorter periods of high-impact loading interspersed throughout the day and performed on a regular basis (Turner & Robling, 2003) may improve bone density, particularly in older females who are at heightened risk of osteoporotic-related fractures. In considering the role of intensity in producing maintaining or increasing bone health, it is important to recognize that a given absolute intensity level of physical activity that may be considered light or moderate for healthy younger adults may, in fact, be fairly demanding for older adults due to their lowered aerobic and muscle strength capacities (Neder, Nery, Silva, Andreoni, & Whipp, 1999). Consequently, regular engagement in typical lifestyle activities spaced throughout the day may yield a sufficient amount of physical stress to maintain or increase bone mineral density in older men and women.

While mechanisms underlying the translation of mechanical forces into metabolic actions remain to be elucidated, the impact of removing mechanical stress on bone mass has been studied in humans (Kohrt et al., 2004). In particular, studies of space flight, bed rest, and spinal cord injury have provided critical evidence indicating that adequate bone remodeling cannot occur without gravitational forces and that weightlessness experienced by astronauts during prolonged spaceflight contributes to drastic bone loss, despite regular exercise (Morseth et al., 2011). Because diminished ground-reaction forces (e.g., bed rest and spinal cord injury) can lead to significant bone loss, these findings have potential application to current lifestyle conditions, which promote and encourage sedentary behavior.

Genetic predisposition to osteoporosis. Approximately 50 to 85% of the variance in peak bone mass is genetically determined (Ralston & de Crombrugghe, 2006), revealing that genetic predisposition is a strong predictor of osteoporosis and a key contributor to fracture risk (Ralston & de Crombrugghe, 2006; Ralston, 2002). Genetic variations in factors influencing bone health are associated with differential response to anabolic and catabolic stimuli, meaning that bone turnover rate can vary across persons of different ethnic backgrounds (Judex, Donahue, & Rubin, 2002). For instance, persons of Caucasian and Asian ethnicities exhibit higher bone turnover rates and potentially greater bone loss compared to African-Americans (Judex et al., 2002). Genetic characteristics of individuals who are more susceptible to osteoporosis include a small body frame, long hip axis length, late menarche, premature menopause (i.e., younger than 45 years of age), and a maternal family history of fractures (Kanis & McCloskey, 1998).

Health-related physical activity

General physical activity recommendations. An accumulating body of evidence reveals the myriad of health improvements which result from engaging in regular physical activity. These benefits include a decreased risk of premature death, cardiovascular disease, Type 2 diabetes, certain site-specific cancers, and osteoporosis (Warburton, Nicol, & Bredin, 2006). For adults aged 18 to 64 years, current health-related physical activity guidelines are to participate in at least 150 minutes of moderate-intensity aerobic physical activity (e.g., brisk walking, water aerobics, bicycling, general gardening, and general dancing), or at least 75 minutes of vigorous-intensity aerobic physical activity (e.g., jogging, running, singles tennis, jumping rope, heavy gardening, and hiking uphill), or an equivalent mixture of moderate- and vigorous-intensity activity. These activities, which should occur at least three days a week (U.S. Department of Health & Human Services, 2008), should be accompanied by daily participation in activities of daily living, such as grocery shopping, housework, and ambulation. Activity episodes lasting at least 10 minutes can count toward meeting aerobic activity guidelines if they are performed at moderate or vigorous levels of intensity (Nelson et al., 2007). The physical activity guidelines also state that adults in this age group should engage in muscle-strengthening exercises requiring the use of all major muscle groups on two or more non-consecutive days a week (Nelson et al., 2007; U.S. Department of Health and Human Services, 2008).

For older adults, modifications have been made to the physical activity guidelines in recognition of the functional limitations and lower fitness levels often seen in this population (Nelson et al., 2007; U.S. Department of Health and Human Services, 2008). For adults aged 65 years and older or adults 50 to 64 years of age with clinically-significant chronic conditions or functional impairments, it is recommended that activity intensity be monitored using a 10-point scale of perceived effort varying from sitting ("0") to all-out effort ("10") (Nelson et al., 2007; U.S. Department of Health and Human Services, 2008). While physical activity guidelines for healthy adults of all ages emphasize the development of aerobic fitness and muscle strength, a balance component was added for older adults to reduce the risk of falls (Nelson et al., 2007; U.S. Department of Health and Human Performance, 2008). In general, older adults should avoid inactivity, and persons with diminished levels of fitness should employ a gradual approach in attaining health-producing levels of physical activity.

Engaging in regular physical activity is also important in promoting the current and future health and fitness status of children and adolescents (U.S. Department of Health & Human Services, 2008). In youth, participation in daily physical activity can exert a positive influence in reducing risk factors for cardiovascular disease, Type 2 diabetes, and obesity (Biddle, Gorely, & Stensel, 2004). Current activity guidelines for children and adolescents aged 6 to 17 years are to engage in 60 minutes or more of daily physical activity to maintain and improve aerobic fitness, muscle strength, and bone health. Most of the daily activity time should be devoted to performing moderate- to vigorous-intensity aerobic activity, with vigorous-intensity activity being performed a minimum of three days a week. In addition, young people should also participate in muscle- and bone-strengthening activities at least three days a week as part of their hourly or longer routine of daily physical activity. From a developmental perspective, children should engage in a variety of physical activities that are enjoyable and age-appropriate (U.S. Department of Health & Human Services, 2008).

Physical activity and bone health for adults. In considering the relationship between physical activity and bone health (Kohrt et al., 2004), the primary goal is to maintain bone mass accumulated over the first three decades of life. Though no clear dose-response relationship exists, the relative risk of osteoporosis can be lowered by being physically active, and these activities do not necessarily have to be vigorous in nature (Kohrt et al., 2004). Current physical activity guidelines to preserve bone mineral during adulthood are to engage in weight-bearing endurance activities (e.g., tennis, stair climbing, and jogging) three to five days per week and participate in activities that feature jumping (e.g., volleyball and basketball) and/or weight lifting two to three days per week. It is recommended 30 to 60 minutes of a combination of these three activity modes should be accumulated daily (Kohrt et al., 2004). Especially for older adults, extra muscle strengthening activity and higher-impact weight-bearing activities should be performed, as tolerated (Nelson et al., 2007). Because there are only a limited number of large randomized-controlled trials which have investigated the dose-response relationship between exercise and bone health, more research is needed to determine the optimal interaction among intensity, frequency, and duration parameters of activities which improve bone health in younger, middle-aged, and older adults.

Physical activity and bone health in youth. A unique aspect of physical activity guidelines for youth is the inclusion of bone-strengthening activities performed on a daily basis. The emphasis placed on developing healthy and strong bones in children and adolescents is based on data highlighting both the role of weight-bearing impact activities (e.g., running, jumping, gymnastics, basketball, and soccer) on bone development and findings which reveal that peak bone mass is attained during the first two to three decades of life (Boreham & Riddoch, 2001; Kohrt et al., 2004). In the *American College of Sports Medicine Position Stand on Physical Activity and Bone Health* (Kohrt et al., 2004), specific guidance is provided for building strong bones in children and adolescents. As with adult and older adult populations, research focusing on the dose-response relationship between physical activity and skeletal development in this population is lacking. However, impact activities (e.g., gymnastics, plyometrics, basketball, and soccer) performed three days a week for a total of 10 to 20 minutes per day in multiple, shorter bouts may promote bone growth and augment bone mineral accrual in children and adolescents (Kohrt et al., 2004).

The primary aim of engaging in regular physical activity during childhood and adolescence in relation to bone health is to maximize peak bone mass in order to minimize the risk of osteoporosis and fall-induced fractures later in life (Gunter et al., 2012). Emerging research on physical activity and skeletal development during childhood and adolescence suggests that bone is particularly responsive to mechanical loading activities (e.g., gymnastics, plyometrics, and jumping) performed during pre-and early-pubertal developmental stages (Gunter et al., 2012). It is well-established, for example, that gymnastics participation during the pre-pubescent years can augment bone mineral accrual (Courteix, Lesessailles, Jaffre, Ober, & Benhamou, 1999; Ward, Robers, Adams, & Mughal, 2005) and gains in bone mass resulting from gymnastics participation before puberty may have a residual effect on BMD in adulthood (Bass et al., 1998; Kirchner, Lewis, & O'Connor, 1996). Similar findings in youth have been reported when comparing the effects of high-intensity and impact activities (e.g., running, jumping) to low-impact (e.g., walking) or non-weight bearing (e.g., swimming, cycling) activities (Kohrt et al., 2004) and plyometric-type activities and sports have also been shown to produce ground-reaction forces six to eight times greater than body weight, while forces generated during walking are only one to two times body weight (McNitt-Gray, 1993). Viewed collectively, this collection of studies suggests that children should engage in activities such as jumping, skipping, and running that produce relatively high-impact loading and maximize bone mass (Kohrt et al., 2004).

During puberty, and especially in the early stages of puberty, bone structure and bone strength markedly increase (Gunter et al., 2012; Hind & Burrows, 2007; MacKelvie et al. 2002; Rizzoli et al., 2010). During this stage of biological maturation, an increase in levels of growth hormone and insulin-like growth factors leads to increased bone formation and bone resorption (Raisz, 1999). Mechanical loading generated from physical activity, coupled with the natural increase in growth hormone, facilitate osteoclastic and osteoblastic processes and promote greater bone mass and bone strength (Robling et al., 2006).

Current recommendations for youth are to engage in impact-loading, moderate-to-vigorous intensity activities for approximately 40 minutes per day to improve bone health at the hip (Janz et al., 2004). It has also been shown that performing 10 to 15 minutes of jumping exercise three days a week for periods lasting four to eight years can promote bone mineral accrual in growing youth (Gunter et al., 2008). However, the potential benefits of participating in shorter-term programs of impact loading during childhood and adolescence remain to be elucidated.

Measurement of physical activity

Introduction. Over the past few decades, the assessment of physical activity has achieved greater prominence in health and fitness research and various approaches have been employed to monitor physical activity levels in persons of all ages (Hart, Ainsworth, & Tudor-Locke, 2011). Overall, physical activity can be measured using subjective or objective measurement instruments (Paffenbarger, Blair, Lee, & Hyde, 1993; Reilly et al., 2008). Examples of subjective and objective measures of physical activity can be found in Table 3.

Subjective measures of physical activity. A widely-used approach to evaluate physical activity is a self- or interview-administered questionnaire. This type of measurement tool was originally developed for use in epidemiological studies (e.g., Harvard Alumni Health Study, Framingham Heart Study) to document the relationship between physical activity and health in former college students and middle-aged men and women, respectively (Paffenbarger et al., 1993). Although self-administered questionnaires are relatively inexpensive and easily administered to large groups, the amount of physical activity reported using these questionnaires may be biased, especially in pediatric and elderly populations (Baumann et al., 2009; Reilly et al., 2008).

A commonly-administered self-report questionnaire in physical activity intervention studies is the 3-Day Bouchard Activity Record (3-Day BAR). The 3-Day

BAR is broken up into 15-minute recording blocks over a 24-hour span and enables participants to identify behaviors and physical activities spanning a wide range of intensities (e.g., including lying, light, moderate, vigorous, and very vigorous; MET range = 1.0 to 7.8) (Bouchard et al., 1983). The total activity time in minutes and daily energy expenditure are then computed per day and monitored over a 3-day period (two weekdays and one weekend day) (Bouchard et al., 1983). The repeatability of energy expenditure estimates using the BAR is quite high (r = 0.96 (Bouchard et al., 1983). While a positive correlation was detected between free-living physical activity measured using the 3-Day BAR and physical activity obtained from a TriTec accelerometer (r = 0.72) (Wickel, Welk, & Eisenmann, 2006), a weak correlation was observed between activity levels obtained from the 3-Day BAR and uniaxial accelerometry (r = 0.23) (Schmidt, Freedson, Chasan-Taber, 2003). Despite the advantage of using the BAR in capturing intensities of physical activity, its accuracy in estimating daily energy expenditure depends on the ability to remember activities throughout the day and correctly identify appropriate activity codes (Schmidt et al., 2003; Wickel et al., 2006).

Another example of a self-report physical activity questionnaire is the International Physical Activity Questionnaire (IPAQ), which was developed to assess frequency and duration of physical activity (i.e., walking, moderate-intensity, and vigorous-intensity activities) and time spent sitting or lying over the past seven days in young and middle-aged adults (i.e., 15 to 69 years of age) from 12 different countries (Craig et al., 2003). Findings from this investigation demonstrated acceptable reliability (ρ = 0.81) and criterion validity (ρ = 0.33) when compared to data collected using accelerometers (Craig et al., 2003). Like other self-reported activity measures, the IPAQ may tend to overestimate physical activity levels in adults (Sallis & Saelens, 2000). Another limitation of IPAQ is the possibility of respondents experiencing difficulty in distinguishing between moderate- and vigorous-intensity physical activities (Baumann et al., 2009).

With respect to the older adult population, there are a number of studies in which the reproducibility and validity of self-administered questionnaires has been studied (Forsen et al., 2010). A self-report physical activity questionnaire used in studies of older persons is the Physical Activity Scale for the Elderly (PASE), which evaluates physical activity levels that are commonly performed by older adults (e.g., occupational, home-, and recreationally-based activities that are light in intensity) over the past week (Forsen et al., 2010). In one study comparing baseline physical activity levels of men and women aged 65 to 99 years with activity levels measured after three to seven weeks (Forsen et al., 2010), the PASE demonstrated a high level of reliability (r = 0.84) in assessing physical activities that are commonly engaged in by older adults. However, other investigations have reported inconsistent test-retest reliability values using the PASE (Forsen et al., 2010). It should be noted that the interview-based form of PASE is extremely reliable (r = 0.91) and may provide researchers with a better estimation of the physical activity level of older adults (Forsen et al., 2010). The PASE exhibited high validity (rho = 0.68) when energy expenditure in elderly men and women was compared against energy values obtained using the doubly-labeled water method (Schuit, Schouten, Westerterp, & Saris, 1997). However, it has been suggested that the validity of the PASE in measuring the time spent in physical activities of the healthy elderly (≥ 65 years of age) could be improved when compared to accelerometer-derived physical activity (Hagiwara, Ito, Sawai, & Kazuma, 2008).

Another self-administered physical activity questionnaire for older adults that has been well-studied in terms of its validity and reliability is the Community Healthy Activities Model Program for Seniors (CHAMPS). In a recent report, the CHAMPS questionnaire was used to gauge the types and intensities of physical activity (including light-intensity activity) that older men and women (65 years or older) engaged in during a typical week over the past month. Though the CHAMPS questionnaire requires a longer time (i.e., 15 to 30 minutes) to complete compared to the PASE (i.e., ~5 minutes), the CHAMPS questionnaire was deemed capable of describing and evaluating meaningful and appropriate physical activities for older adults (Forsen et al., 2010). The test-retest reliability (i.e., intraclass correlation coefficient; ICC) for the CHAMPS questionnaire in measuring weekly frequency and time spent in moderate- to vigorous-intensity physical activities is moderately strong, with ICC values ranging from 0.75 to 0.79. As with the Physical Activity Scale for the Elderly, the construct validity of the CHAMPS questionnaire in measuring walking frequency per week is less than desirable (*rho* = 0.57). Despite this limitation, however, both the PASE and the CHAMPS can adequately classify older adults into physical activity categories (Forsen et al., 2010).

Objective measures of physical activity. While subjective measures of physical activity may result in the overestimation or underestimation of an individual's physical activity level, objective measures of physical activity enable researchers to reliably and accurately capture activity levels in youth and adults that are associated with health outcomes. The two primary motion sensors that have been used in activity-promoting studies are pedometers and accelerometers. While certain brands of validated and reliable pedometers (e.g., Omron, New Lifestyles (NL) 1000) are relatively inexpensive and can accurately register the number of step counts taken during intermittent or continuous walking bouts performed at moderate to vigorous intensities, they are limited in their ability to accurately estimate daily energy expenditure and/or time spent in light-intensity activities. While the use of pedometers has allowed investigators to provide step activity recommendations for preschool children, adolescents, adults, healthy older adults, and individuals with disability or chronic disease (Tudor-Locke et al., 2011), this activity monitoring device may not necessarily be well-suited to classify sedentary and light-intensity activities. Considering that many older men and women (70 years of age or older) do not meet current physical activity recommendations for health (Davis & Fox, 2007), and given that the majority of their daily living activities include light-intensity physical activities (Copeland & Esliger, 2009), the use of pedometers may not be ideal when tracking changes in the physical activities of older adults.

Accelerometers are another type of activity monitoring device capable of monitoring stepping levels and movement or activity counts which can subsequently be used to estimate energy expenditure and categorize various physical activities relative to light, moderate, and vigorous intensity (Butte, Ekelun, & Westerterp, 2012). In this regard, one of the most commonly-used accelerometers is the ActiGraph (ActiGraph, Pensacola, PA). Two versions of the current generation of ActiGraph monitors, (GT1M and GT3X), allow for uniaxial (i.e., vertical) and triaxial (i.e., vertical, antero-posterior, and vector magnitudes of the two axes) measures of physical movement, respectively, to be recorded (Tudor-Locke & Rowe, 2012). The GT1M model has been validated in measuring stepping activity during controlled treadmill walks at speeds equal to and greater than three miles per hour with less than 3% absolute percent error (APE) (McClain, Hart, Getz, & Tudor-Locke, 2010; Abel et al., 2008). At slower walking speeds (e.g., two miles per hour), the ActiGraph displayed less accuracy by undercounting the number of steps taken by adults (Abel et al., 2008). Daily energy expenditure can be estimated from Actigraph data by employing a previously published regression equation (Rothney, Schaefer, Neumann, Choi, & Chen, 2008). When energy use predicted by the ActiGraph was compared with energy expenditure measured using a room calorimeter, less than a 2% error rate between both metabolic techniques was present when moderate- and vigorous- intensity physical activities were performed. In contrast, energy expenditure values predicted by the ActiGraph during moderate- to vigorous-intensity activity underestimated actual energy expenditure quantified using indirect calorimetry (i.e., portable oxygen analyzer) (Berntsen et al., 2010). Moreover, because the ActiGraph can be less accurate in estimating energy demands during sedentary and light-intensity physical activity (Rothney, Apker, Song, & Chen, 2008), the development of regression models specific to specific intensity categories of physical activity is warranted (Rothney et al., 2008).

In considering the ability of the ActiGraph accelerometers to monitor activity counts, data obtained from the triaxial GT3X and the GT1M in children (Hanggi, Phillips, & Rowlands, 2013) and adults (Sasaki, John, & Freedson, 2011) were analyzed. Results from these studies showed that vertical activity counts registered by both accelerometers were similar in adults (Sasaki et al., 2011), but differed in children during running (Hanggi et al., 2013). While the triaxial feature of the GT3X allows for examination of how differences in posture influence energy use during various physical activities, caution should be applied when comparing activity counts obtained from the GT3X to activity counts derived from the GT1X, especially when studying pediatric populations (Hanggi et al., 2013). Another unique feature of the ActiGraph monitoring device is its ability to differentiate among intensity levels of various activities (e.g., sedentary, light, and moderate- to vigorous-intensity activities), which can be especially relevant when studying older adults (Copeland & Esliger, 2009). In this regard, a study by Copeland and Esliger (2009) established a cutoff point of activity counts per minute that can be employed to define moderate- to vigorous-intensity activities in older adults. By using 1,041 counts per minute as a cutoff value, these authors reported that older individuals accumulated an average of 68 minutes of moderate- to vigorous-intensity activity per day and nearly 14 hours per day of light-intensity activity (Copeland & Egliger, 2009). Although further research is needed to set appropriate classification points to define sedentary and light-intensity activities, the ActiGraph can be used to identify physical activity patterns and track changes in activity levels in older adults.

The activPAL accelerometer (PAL Technologies, Ltd., Glasgow, UK) has also been utilized in research studies to measure physical activity. The activPAL is highly accurate (i.e., < 2% APE) in measuring stepping activities during controlled treadmill walks at speeds above 1.3 miles per hour (Maddocks, Petrou, Skipper, & Wilcock, 2010). The APE of step counts as measured by the activPAL and direct observation was less than 1% during controlled treadmill walks at speeds faster than two miles per hour and during overground walks at self-selected speeds greater than 3.1 miles per hour (Ryan, Grant, Tigbe, & Granat, 2006). The activPAL monitor also functions as an inclinometer because of its ability to detect postural differences (e.g., moving from sitting to standing or sitting to lying). A validation study by Ryde, Gilson, Suppini and Brown (2012) demonstrated an extremely high level of agreement (ICC = 0.99) between time spent in desk-based sitting and chair-based transitions as quantified by the activPAL and camera-derived direct observation (Ryde et al., 2012). Consequently, use of the activPAL may be suitable when evaluating changes in light-intensity or sedentary activities representative of many occupational settings or occur during desk-based transitions (Ryde et al., 2012).

The SenseWear Armband (BodyMedia, Inc., Pittsburgh, PA), a triaxial accelerometer worn on the upper arm, documents stepping activity, activity duration and intensity, and estimates energy use continuously throughout the day. A validation study conducted by Dwyer, Alison, McKeough, Elkins, and Bye (2009) yielded a reasonably accurate estimate of step counts and energy expenditure during treadmill walking at an average speed of 3.4 miles per hour in healthy individuals and persons with cystic fibrosis. When energy expenditure and stepping activity estimates from the SenseWear Armband were compared with those derived from a pedometer in older adults and individuals with chronic obstructive pulmonary disease (Furlanetto et al., 2010), energy expenditure values from the SenseWear Armband were more accurate than values obtained from pedometer use during treadmill walking at various speeds. In addition, the accuracy of SenseWear step counts improved as walking speeds increased (Furlanetto et al., 2010). While acknowledging the validity of the SenseWear monitor in estimating daily energy expenditure in a controlled activity setting, further research is needed to validate this device in free-living conditions while participating in a variety of lifestyle activities. Additional studies are also needed to validate the ability of the SenseWear

Armband to quantify time spent in light-intensity activities and accurately estimate daily energy expenditure during light-, moderate-, and vigorous intensity activities performed by youth and adults of all ages.

An activity monitoring device that is suitable for measuring ambulatory activity in populations with functional limitations is the StepWatch Activity Monitor (SAM) (Bassett & John, 2010). The SAM is an ankle-mounted accelerometer with a high degree of accuracy (99.7%) in measuring step counts during controlled treadmill walks across a wide range of speeds (i.e., 1 to 3 mph). The SAM has also been validated and used to document step activity patterns in persons with atypical gait patterns, including older adults living in assisted-living facilities (Bergman, Bassett, Muthudrishnan, & Klein, 2008), stroke patients (Mudge, Stott, & Walt, 2007), and adults with multiple sclerosis and Parkinson's disease (Schmidt, Pennypacker, Thrush, Leiper, & Craik, 2011) and chronic obstructive pulmonary disease (Nguyen, Burr, Gill, & Coleman, 2011). Another advantage of the SAM device is its ability to store large amounts of data for up to two months. Because a potential drawback of the SAM is its cost, relative to other motion-sensing instruments (Tudor-Locke & Rowe, 2012), the use of the SAM in studies with large numbers of participants may be problematic.

In summary, gathering reliable and valid physical activity data is a critical prerequisite to accurately describing movement profiles and quantifying the effects of various interventions and therapies on the activity patterns of various subject populations. Based on the strengths and limitations of various types of motion-sensing devices which currently exist, researchers and clinicians should select the activity measurement tool best suited to the population of interest.

Impact of physical activity on bone health in older women. A number of meta-analyses have quantified the effects of physical activity on bone mass in pre- and post-menopausal women (see Table 4). As shown in this table, a meta-analysis by Kelley (1998) reported a positive moderate benefit (effect size = 0.43) of hip-loading aerobic exercise on hip BMD in postmenopausal women, such that BMD values rose by approximately 2% over pre-intervention values. Because studies in this review varied with respect to the exercise parameters studied (i.e., frequency, intensity, and duration), the ideal dosage of aerobic-type exercise needed to enhance bone density in older women cannot be specified (Kelley, 1998). As noted by Kohrt and colleagues (2004), moderate- to high- intensity weight-bearing activities are recommended to most effectively maintain bone density in adulthood. However, aerobic exercises performed at a moderate-intensity and frequently distributed throughout the day and week may be desirable for many older individuals, as low exercise adherence has been observed among older individuals who participate in high-intensity exercise programs (Kelley, 1998). Another meta-analysis (Wolff, van Croonenborg, Kember, Kostense, & Twisk, 1999), which combined various randomized and non-randomized controlled trials, concluded that a minimum of 16 weeks of endurance and/or strength-training programs can preserve bone mass or even reverse close to 1% of bone loss each year at the lumbar spine and femoral neck in pre- and post-menopasual women. In contrast, a more recent overview of studies documenting the efficacy of resistance training in premenopausal women (18 to 47 years of age) reported no positive effects on BMD at the lumbar spine and femoral neck (Kelley & Kelley, 2004). Furthermore, when walking-only interventions were examined (Palombaro, 2005); a meta-analysis featuring 10 studies of women 50 years and older revealed a moderate effect on BMD at the lumbar spine, but very minimal to no effects on BMD at the femur or calcaneus. Based on calculations of six different effect sizes, a systematic review of exercise training on BMD in older women reported a positive effect of progressive high-intensity resistance training on lumbar spine BMD, but no effect on femoral neck BMD, in premonopausal females (Martyn-St James & Carroll, 2006). This discrepancy among meta-analyses regarding the extent of training-related improvements in bone mass at lumbar spine and femoral neck in pre- and post-menopausal females may reflect differences in the length of the intervention trials and the number of available effect sizes. Clearly, additional well-designed physical activity programs are needed to attain consensus on the specific dose(s) of physical activity and exercise needed to successfully maintain bone health in older females.

One of the challenges of documenting the role of weight-bearing exercise and resistance training on bone health in older females is that longer intervention periods are often required to observe increases in BMD due to a relatively slow rate of bone metabolism (Humphries et al., 2000) Consequently, short-term (e.g., less than six months) exercise interventions do not produce significant positive gains in BMD, particularly in older women whose bone turnover is slower compared to younger adults (Humphries et al., 2000). Given this scenario, measurement of bone metabolism markers, such as serum alkaline phosphatase, osteocalcin, and urinary deoxypyridinoline, may provide insight regarding possible mechanisms responsible for changes in bone structure occurring early in an activity-based program, but which remain undetectable using DXA or other imaging devices (Jessup et al., 2003).

A study conducted by Young, Weeks, and Beck (2007) documented the effects of a simple 12-month physical activity program (i.e., line dancing in concert with squatting exercise and/or foot stamping activities) designed to improve lower-extremity muscular strength and balance in sedentary, postmenopausal Caucasian women. Although no significant gains in proximal femur and lumbar spine BMD were observed across participant groups (Group 1: line dancing once a week; Group 2: line dancing and progressively-loaded squats five time a week; Group 3: line dancing, squats, and foot stamping twice a day, five times a week), there was a significant positive association between compliance with the prescribed activity (foot stamping and squatting) and proximal femur BMD in Group 3 participants (Young et al., 2007). This type of activity program may be especially appealing to older females, as it highlights the potential upside of engaging in less-intense and enjoyable weight-bearing physical activity that can minimize bone loss and reduce the risk of osteoporotic-related fractures. Table 5 provides a summary of the effects of exercise interventions (mainly strength training) on bone health, muscular strength and balance in pre- and post-menopausal women. In reviewing these findings, it is interesting to note that studies in which exercise occurred three or more times a week displayed an increase in muscular strength and either improved or preserved BMD, whereas studies in which sessions were held twice a week showed no difference in BMD values following exercise intervention. Although speculative, these data suggest that frequency of physical activity may be an important exercise parameter related to the maintenance and improvement of bone mass in older females.

Sedentary behaviors and bone health

Definition of sedentary behavior. Distinct from the lack of physical activity (Gardiner, Eaking, Healy, & Owen, 2011; Owen et al., 2011; Tremblay, Colley, Saunders, Healy, & Owen, 2010), sedentary behavior is typically defined as prolonged inactivity, the absence of whole-body movement (Healy et al., 2008), or simply sitting too much. Sedentary behaviors are mainly sitting or reclining activities that feature a low energy expenditure (1.5 METS or less) (Tremblay et al., 2010) and include behavior domains such as occupational, leisure-time, transport, and household pursuits (Owen et al., 2011). Opportunities for youth and adults to engage in sedentary activities, such as driving to work, typing on a computer at work, eating, and watching television, abound in most industrialized societies (Hamilton Healy, Dunstan, Zderic, & Owen, 2008; Tremblay et al., 2010).

Health-related impact of sedentary living. Studies of the underlying physiology of sedentary living have highlighted a number of negative health consequences, especially when sedentary activities occur frequently throughout the day (Hamilton et al., 2008). Physical inactivity has been associated with impaired glucose and lipid metabolism (Ford, Kohl, Mokdad, & Ajani, 2005), greater all-cause mortality (Dunstan et al., 2010; Patel et al., 2010; Stamatakis, Hamer, & Dunstan, 2011; van der Ploeg, Chey, Korda, & Bauman, 2012), and clinically significant cardiac events, including myocardial infarction, coronary artery bypass, angioplasty, stroke, heart failure and cardiovascular-related death (Stamatakis et al., 2011). While not definitive, recent increases in obesity and Type 2 diabetes among children and adolescents may reflect the health-related impact of sedentariness and insufficient physical activity in this group (Biddle et al., 2004). It has also been speculated that a link exists between inactivity-induced adiposity, poor bone health, and increased cardiovascular disease risk during childhood and future health status in adulthood (Biddle et al., 2004).

Assessment of sedentary behaviors. Sedentary behaviors can be quantified in a number of ways. Examples of subjective and objective approaches to measuring sedentary behaviors include identification of sedentary behaviors, assessment of the frequency and duration of sedentary behaviors (including chair time and/or screen time), measurement of energy expenditure and daily step activity, and determination of the number of minutes below the threshold of light-intensity activities (less than 100 activity counts or units of body acceleration) per minute (Tremblay et al., 2010). These indices of sedentary behavior have been evaluated using portable indirect calorimetry, questionnaire, interview, and activity-recall instruments, and motion sensors such as pedometers and accelerometers (Tremblay et al., 2010). Examples of instruments which have been employed to obtain subjective and objective measures of sedentary behaviors and physical activity are shown in Table 3.

A common approach used to evaluate sedentary behavior is to ask a single question in an interview or activity-based questionnaire format concerning the amount of total time spent sitting or lying down (Clemes, David, Zhao, Han, & Brown, 2012; Fogelholm et al., 2006). Because this approach provides limited data regarding the sedentary lifestyle of an individual, it can be challenging for researchers or health professionals to develop targeted behavioral change intervention programs to reduce sedentary behaviors. In an attempt to address this issue, work is presently being conducted at Middle Tennessee State University (MTSU) to develop a Sedentary

Behavior Record for Adults (SBR-A). This questionnaire, which is structured in a similar manner as the 3-Day Bouchard Activity Record (Bouchard et al., 1983), consists of 15-minute time blocks for participants to complete using numbers which correspond to specific sedentary behaviors (e.g., sleeping, lying while using electronic devices, lying while reading and socializing, work-related sitting, non-work-related sitting, and transitioning) typical of a wide array of screen- and non-screen-based activities and time spent in work- and non-work-related settings. Because the SBR-A describes patterns of sedentary behavior throughout an entire week, individualized and targeted interventions can be created to effectively minimize time devoted to sedentary pursuits. At present, data are being collected over a 7-day period and Generalizability theory will be used to determine the minimal number of monitoring days needed to reliably estimate individual sedentary behavior.

Objective measures of sedentary behavior. Several accelerometry devices have been validated to document sedentary behavior. These include the ActiGraph and the activPAL. The activPAL device is capable of monitoring shifts in posture (e.g., moving from lying to sitting to standing and vice-versa). A validation study conducted by Ryde et al. (2012) demonstrated a high level of correlation between sitting time (ICC = 0.99) and chair-based transitioning time (ICC = 0.93) obtained from ActivePAL and camera recording. Although the activPAL appears to exhibit a higher sensitivity to reductions in sitting time compared to the ActiGraph (Kozey-Keadle, Libertine, Lynden, Staudenmayer, & Freedson, 2011), a study by Gardiner et al. (2011) reported an acceptable test-retest reliability (rho = 0.52) and validity (rho = 0.30) when documenting sedentary time in older adults, implying its suitability for use in intervention studies featuring this population. Because the ActiGraph may underestimate sitting time by close to 5% of actual sitting time (Kozey-Keadle et al., 2011), the use of less than 150 activity counts per minute (rather than 100 activity counts per minute) may be appropriate as a threshold for defining sedentary behavior.

Feasibility of reducing sedentary behavior. An innovative method of reducing sedentary behavior in youth has been to modify physical inactivity through a behavioral change approach (Epstein & Roemmich, 2001). In brief, this approach is based on the premise that a potentially undesirable behavior (like physical inactivity) can be reduced by substituting a more desirable behavior (e.g., physical activity) in its place. A review by Epstein and Roemmich (2001) also noted that encouraging obese children to reduce highly-preferred sedentary behaviors (i.e., playing video games, watching television, and using computers) is significantly more effective than punishing or restricting children from engaging in these behaviors (Epstein & Roemmich, 2001). Moreover, when participation in targeted sedentary activities (i.e., video games and movies) occurred simultaneously with bike pedaling, obese children significantly increased the amount of time spent in physical activity (i.e., cycling) (Epstein & Roemmich, 2001). While strategies to reduce sedentary behaviors among youth have been discussed in the literature, relatively little is known concerning the possible impact of targeted programs on decreasing sedentary behavior in middle- to older-aged groups (Brawley, Rejeski, & King, 2003). Hence, additional research is needed to document the long-term success of behavioral change programs aimed at reducing sedentary behavior throughout a person's lifetime (Garber et al., 2011).

A limited number of feasibility studies have been conducted to gauge the success of replacing sedentary behaviors with light activities or activities of daily living (Gardiner et al., 2011). In one study (Gardiner et al., 2011), 59 males and females (ages 60 years and older) who self-reported watching two or more TV hours per day attended a 45-minute session with an investigator to learn about goal setting and self-monitoring of sedentary behaviors followed by a mailing of individualized feedback to participants based on their sedentary behavior profile. Results from accelerometry data acquired before and immediately after the meeting with the researcher indicated that sedentary time was decreased significantly. In work by Healy et al. (2008), a significant association was observed between sedentary time and metabolic risk (i.e., waist circumference, body mass index, triglycerides, and 2-hour plasma glucose) in middle-aged adults (age = 53.4 ± 11.8 years). In this study, frequency of breaks in sedentary time, as measured by accelerometry (≥ 100 activity counts per minute), was tied to a lower metabolic risk, independent of total sedentary and moderate-to-vigorous intensity activity time. More specifically, a greater number of interruptions or breaks in sedentary time were linked to lower BMI, waist circumference, triglycerides, and plasma glucose levels (Healy et al., 2008). From a mechanistic perspective, the authors of this paper speculated that the absence of skeletal muscle contractions caused by physical inactivity could have resulted in a decreased clearance of plasma triglycerides and lower glucose turnover, thus elevating the risk of metabolic dysfunction. In summary, these findings suggest that prolonged periods of sedentary behavior can lead to adiposity and abnormal glucose metabolism.

In a recent paper, Kozey-Keadle, Libertine, Staudenmayer, and Freedson (2012) implemented a simple, 1-week long feasibility intervention to replace sedentary behaviors with light-intensity activities in overweight, non-exercising office workers (age range of 20 to 60 years). After monitoring physical activity over a 7-day period, participants were given a packet of instructional materials featuring ways to reduce sedentary time by incorporating behavioral modification strategies at home, work, and during recreation and transportation. A checklist was also provided to participants so that they could monitor their sedentary behaviors over the next seven consecutive days. After the second 7-day activity monitoring period, baseline sedentary behavior as measured by the ActiGraph was compared to the sedentary behavior of the second 7-day time frame. Findings from this study indicated that sedentary time was reduced approximately 50 minutes per day by replacing sedentary behaviors with standing and/or light activities such as walking while talking on the phone, washing dishes by hand instead of using the dishwasher, taking a 5-minute walk or stand break every hour, using the stairs instead of the elevator, engaging in active recreational pursuits (e.g., bowling and swimming), and volunteering to walk the dog or play with children.

Behavioral change intervention studies in older adults. In recognition of the positive association between physical inactivity and negative health outcomes in older adults (Nelson et al., 2007), there is growing interest in developing and implementing programs to raise physical activity levels in this population (Brawley et al., 2003). Questions linger, however, regarding the practical extent to which health care practitioners can influence older men and women to alter their current activity status and maintain changes in modified behaviors, especially in light of data showing that the majority (~70%) of asymptomatic older adults aged 50 years and above do not meet the current physical activity guidelines for Americans (U.S. Department of Health and Human Services, 2000). A theory-based approach which may be useful in developing and implementing practical approaches to decrease sedentary behavior and promote a more active lifestyle in older persons is the behavioral change model (Brawley et al., 2003). In brief, this model conceptualizes the process of intentional behavioral change and consists of the following components: 1) identifying the goal of the individual; 2) self-monitoring of the behavior that is to be changed; 3) receiving feedback and information regarding progress toward the goal; 4) self-evaluating progress that has occurred; and 5) correcting or reinforcing the behavior to successfully achieve the individual's goal.

On a simplistic level, it seems reasonable to assume that older adults with low fitness levels may require several months to engage in and sustain moderate-to-vigorous levels of physical activity. Not only can barriers, such as pain, poor health, environmental limitations and lack of knowledge (Schutzer & Graves, 2004) prevent older adults from initiating positive lifestyle changes, but misconceptions regarding physical activity (e.g., exercise must be strenuous or uncomfortable to benefit health) can also pose challenges, especially among older women interested in becoming more active (Lee, 1993). Therefore, a primary goal for older adults is to focus on increasing functional mobility before aiming to improve other aspects of health-related fitness, such as aerobic fitness or body composition (Brawley et al., 2003). A contemporary approach towards achieving better walking performance is to systematically increase the amount of time spent in activities of daily living that are more easily and continuously performed by older individuals (Brawley et al., 2003).

The U.S. Preventive Services Task Force (2012) recently published guidelines for behavioral interventions which are geared towards promoting healthy lifestyles and preventing cardiovascular disease in adults without known disease. To summarize, these guidelines state that individual behavioral counseling performed by clinicians is beneficial in improving health outcomes (i.e., decreased blood pressure, decreased blood lipid levels, and improved glucose tolerance) in apparently healthy adults. In the task force document, it was reported that behavioral interventions conducted at medium- and high-intensity levels produced positive health benefits. The task force defined various intensities of behavioral counseling interventions as a function of patient contact minutes (i.e., low = 1 to 30 minutes; medium = 31 to 360 minutes; high = greater than 360 minutes), number of patient contact sessions, and the nature of the patient contact. To elaborate, low-intensity interventions consisted of one to two single, short sessions with a health provider or other comparably-trained person, medium-intensity interventions were comprised of 3 to 24 contacts via telephone or 1 to 8 in-person sessions, and high-intensity interventions consisted of 4 to 20 group sessions over various intervention periods (U.S. Preventive Services Task Force, 2012). According to the task force document, only high-intensity interventions produced sustained behavioral changes beyond a 12-month period (U.S. Preventive Services Task Force, 2012). In work conducted by Fukuoka, Vittinghoff, Jong, and Haskell (2010), sedentary females aged 25 to 70 years completed a 3-week mobile phone-based physical activity program aimed at elevating stepping activity. Diary prompts provided to the female participants, which required them to report their daily step counts at the end of each day, led to increased motivation to become more physically active (Fukuoka et al., 2010). Current findings suggest that a healthy diet, physical activity counseling trials, or a combination of both intervention approaches performed at medium- to high-intensity result in a decrease in self-reported dietary intake of salt, calories, and fat, a rise in fruit and vegetable consumption, and an increase in self-reported physical activity (U.S. Preventive Services Task Force, 2012). At present, little is known regarding the impact of the number of patient contacts on reductions in sedentary behaviors in younger and older adults. However, it is reasonable to speculate that older individuals who receive a greater number of contacts consisting of personalized feedback and reinforcement may display a greater reduction in sedentary behavior compared to those who do not receive contacts or receive a limited number of contacts.

In the latest position stand on the quality and quantity of physical activity for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults by the American College of Sports Medicine (ACSM) (2011), it was noted that positive health outcomes occur in healthy adults, even if recommended amounts of physical activity (i.e., 30 or minutes of moderate- to vigorous-intensity physical activity on five or more days per week) are not attained. Based on these findings, the ACSM position stand recommended that total sedentary time be decreased by engaging in short bouts of standing or physical activity interspersed between sedentary behaviors (Garber et al., 2011). Interestingly, reducing sedentary activity was also advocated for adults who currently meet ACSM activity guideline (2011). According to Garber and colleagues (2011), keys to making positive behavioral changes include adopting individually-tailored behavior change strategies (i.e., goal setting, social support, reinforcement, problem solving, and relapse prevention) and participation in supervised exercise programs which feature enjoyable activities. When results from 22 studies were analyzed to systematically identify the most effective approaches to devise messages promoting physical activity levels in healthy adults between the ages of 18 to 65 years (Latimar, Brawley, & Bassett, 2010), tailored and gain-framed (i.e., focused on benefits of adopting a target behavior) messages accompanied by general physical activity guidelines were deemed promising motivational strategies to increase exercise adherence (Latimar et al., 2010). While further research is needed, providing individualized messages that relate specifically to the "how to" aspect of changing behavior may be beneficial in helping inactive older persons to reduce the amount of daily time spent in sedentary pursuits.

While few studies have documented long-term physical activity adherence and maintenance (Marcus et al., 2000; Muller-Riemenschneider, Reinhold, Nocon, & Willich, 2008), continued contact and social support seem to be the most effective methods of successfully achieving prolonged success in maintaining exercise programs among older adults (Castro, King, & Brassington, 2001). Given that intervention studies targeting sedentary behavior in older adults are relatively sparse, further research is necessary to develop approaches to help individuals become more active, reduce sedentary behavior, and maintain positive lifestyle changes (Marcus et al., 2000; Owen, Healy, Matthews, & Dunstan, 2010; Sevick et al., 2007).

Activities of daily living. During the 20th century, an increase in the number of older adults in the United States has been accompanied by greater morbidity and more difficulty performing vital activities of daily living (ADL) such as bathing, dressing, transferring, toileting, and feeding (Dunlop, Hughes, & Manheim, 1997; Penninx et al., 2001). It has been reported that approximately 20% of persons aged 70 years and older suffer ADL disability (defined as experiencing some or a lot of difficulty or an inability in performing ADLs) (Kramarow, Lentzner, Saydah, Weeks, & Rooks, 1999), which can lead to a greater loss of independence (Penninx et al., 2001). It has also been suggested that when a wide array of disabilities are considered (i.e., movement, emotional, sensory, and cognitive difficulties, and self-care, social, and work limitations), over 60% of adults aged 65 years and above report some form of disability (U.S. Department of Health and Human Services, 2011). Moreover, a study by Dunlop et al. (1997) revealed that a hierarchy of ADL disability exists (e.g., walking, bathing, transferring, dressing, toileting, and feeding) and that women spend more time in a disabled state due to the early onset of ADL disability. Because walking is the first indication of disability in the elderly, a randomized-controlled clinical trial featuring aerobic exercise (a 3-month supervised walking program followed by a 15-month home-based walking program) or resistance exercise (a 3-month supervised program followed by a 15-month home-based program consisting of progressive upper- and lower-body exercises) was implemented in aging persons (ages 60 years and older) with osteoarthritis (Penninx et al., 2001). Following completion of the trial, participants in both exercise groups displayed a significantly reduced incidence of ADL disability (Penninx et al., 2001).

The first reported ADL disability measure (Katz Index) was designed by Katz, Ford, Moskowitz, Jackson, and Jaffe (1963) nearly 50 years ago and has been validated and used by many investigators (Penninx et al., 2001). A Rasch analysis conducted by Gerrard (2013) in older females and males (average age of 81 years) has shown that the Katz Index fits the Rasch model fairly well and is based on the following hierarchy of activities of daily living: eating, maintaining continence, transferring, toileting, dressing, and bathing (Gerrard, 2013). Nourhashemi et al. (2001) employed an instrumental ADL (IADL) scale and described the relationship between IADL and frailty, which is distinct from disability and refers to an increased risk of functional loss that is still reversible. The IADL scale is a simple and valid tool for evaluating the functional status of elderly individuals (Applegate, Blass, & Williams, 1990) and consists of eight items which evaluate a person's ability to travel, shop for groceries, prepare meals, do housework, launder clothes, use the telephone, take medications, and manage money (Nourhashemi et al., 2001). When using this scale, each task is assessed as "independent," "assistance required," or "dependent." This observational study revealed a significant association between incapacities revealed by the IADL scale and frailty in healthy elderly women. The measurement of functional status using the IADL scale may aid in documenting the effectiveness of specific intervention programs to reduce sedentary behavior in aging women who are still apparently healthy and capable of performing ADLs (Katz et al., 1963).

Summary of literature review

An exhaustive review of the literature highlights the importance of mechanical loading through weight-bearing physical activity to enhance bone remodeling and maximize peak bone mass during childhood and adolescence, maintain bone mass during early and middle adulthood, and minimize bone loss in older adults. The negative impact of sedentary behaviors, such as prolonged sitting, on mortality and health status, independent of physical activity level, has also been demonstrated. Based on studies indicating that the reduction of sedentary behaviors decreases the risk of obesity, helps normalize glucose metabolism, and decreases metabolic syndrome (Healy et al., 2008), it is reasonable to explore whether replacing sedentary pursuits with weight-bearing activities tied to daily living activities can also limit bone mineral loss that occurs naturally with aging.

Two current challenges to promoting lifestyle changes in older adults are to identify the most effective way to minimize barriers and increase motivation to become more physically active. These impediments to embracing a more active lifestyle may resonate more strongly with older women, who display a heightened susceptibility to decreased bone mass, face a greater challenge in meeting recommended levels of physical activity, and exhibit more fall-related fractures. Consequently, it is of particular interest to determine whether replacing sedentary behaviors with weight-supported, light-intensity activities and daily living pursuits is a viable means of maintaining or reducing bone loss in older women.

Table 1

T-score Criteria for Osteopenia and Osteoporosis in Women

Category	T-score	BMD threshold value
Normal	> -1.0 SD	
Osteopenia	-1.0 to -2.5 SD	0.740 g/cm^2
Osteoporosis	≤ -2.5 SD	0.577 g/cm^2
Established Osteoporosis	≤ -2.5 SD with one or more fractures	

Note: Adapted from the World Health Organization Osteoporosis Criteria (Kanis et al., 2000). Cutoff values are based on the data from National Health and Nutrition Examination Survey (NHANES III, 1988-1994) as the reference values for bone mineral density (BMD) at the femoral neck of women 20 to 29 years of age (Kanis et al., 2008; Kanis et al., 2000).

Table 2

T-score Criteria for Osteopenia and Osteoporosis in Men

Category	T-score	BMD threshold value
Normal	> -1.0 SD	
Osteopenia	-1.0 to -2.5 SD	0.792 g/cm^2
Osteoporosis	≤ -2.5 SD	0.585 g/cm^2
Established Osteoporosis	≤ -2.5 SD with one or more fractures	

Note: Adapted from the World Health Organization Osteoporosis Criteria (Kanis et al., 2000). Cutoff values are based on the data from National Health and Nutrition Examination Survey (NHANES III, 1988-1994) as the reference values for bone mineral density (BMD) at the femoral neck of men 20 to 29 years of age.

Table 3

Examples of Qualitative and Quantitative Instruments Used to Assess Physical Activity

Instrument	Description	Units of measure	Features/Limitations
International Physical Activity Questionnaire (IPAQ)	Subjective questionnaire / interview	Total number of minutes per day	Time spent sitting on weekdays and weekend days
Total Sitting Questionnaire (short-version of IPAQ)	Subjective questionnaire / interview	Total number of minutes per day	Simple for participant to answer, yet does not specify types and timing of sedentary behaviors in a day
Bouchard Activity Record (PAR)	Subjective questionnaire / interview	Number of activities in 15-minute intervals per day	Measures the full spectrum of activities from lying and sitting to vigorous intensity physical activities; weak correlation of estimates of physical activity level with activity count data from the ActiGraph
Omron HJ-151 (Omron Healthcare; Kyoto, Japan)	Pedometer (hip)	Steps per day	Measures moderate-to-vigorous intensity step counts; not intended to measure sedentary time; 4-second filter can lead to undercounting of short walking bouts
ActiGraph GT1M/3X (Actigraph; Pensacola, FL)	Accelerometer (hip)	Activity counts per minute	Allows conversions of activity counts per minute to sedentary, light, moderate-to-vigorous intensity activity time

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Table 3 continued

Instrument	Description	Units of measure	Features/Limitations
activPAL Activity Monitor (PAL Technologies, Ltd.; Glasgow, UK)	Accelerometer (thigh)	Minutes in sitting/lying, standing, and stepping	Sensitive to sedentary behaviors and can discriminate among light-intensity activities (sitting/lying vs. walking vs. standing)
StepWatch Activity Monitor (SAM; Orthocare Innovations, LLC; Oklahoma City, OK)	Accelerometer (ankle)	Step counts per day	Sensitivity of the device is adjustable to individual gait patterns; can be used in clinical populations
SenseWear Armband (SWA; BodyMedia, Inc., Pittsburgh, PA)	Calorimeter (upper arm)	kcals per minute, steps per day, and sleeping hours	Can be worn during sleeping hours

Note: Information listed above is adapted from Hart et al. (2011), Rosenberg et al. (2010), and Tudor-Locke and Rowe (2012).

Table 4

Summary Table of Meta-Analyses Related to Effects of Physical Activity and Exercise on Bone Mineral Content and Density in Pre- and Postmenopausal Women

Study	Number of studies	Menopausal status	Exercise Mode	Bone health measures	Results
Kelley (1998)	6	Post	Aerobic exercise	Femoral neck BMD	Moderately positive effect of aerobic exercise at femoral neck
Kelley and Kelley (2004)	3	Pre	Resistance exercise	Lumbar spine and femoral neck BMD	No significance on both lumbar spine and femoral neck BMD
Martyn-St James and Carroll (2006)	11	Pre	Progressive high-intensity resistance training	Lumbar spine and femoral BMD	Possible positive effect of resistance training on BMD at lumbar spine, but not at femoral neck
Palombaro (2005)	10	Post	Walking	Lumbar spine, femoral neck, femur, calcaneus, forearm, and distal radius	No supporting evidence of walking interventions to maintain BMD at various skeletal sites
Wolff et al. (1999)	25	Pre, post	Endurance training and strength training	Lumbar spine and femoral neck BMD	Exercise training prevented or reversed approximately 1% of bone loss per year in lumbar spine and femoral neck

Table 5

Summary Table of Controlled Trials Examining Muscular Strength, Balance, and Self-Efficacy in Relation to Bone Health in Pre- and Postmenopausal Women

Study	Sample (age in years)	Intervention protocol	Bone health measures	Secondary measures	Results
Bocalini, Serra, dos Santos, Murad, and Levy (2009)	Post-menopausal *N* = 25 (57-75)	Strength training; three times a week for 24 weeks	Lumbar spine and femoral neck BMD	1RM chest press and leg extension	Trained group increased strength, preserved BMD, and improved body composition
Jessup et al. (2003)	Post-menopausal *N* = 18 (69.2 ± 3.5)	Strength training, load-bearing walking, stair climbing, and balance training exercises; three 60-minute sessions per week for 8 months	Lumbar spine and femoral neck BMD	Strength, body sway, bone metabolism biomarkers (e.g., osteocalcin)	Exercise group improved femoral neck BMD and balance
Humphries et al. (2000)	Peri- and post-menopausal *N* = 64 (45-65)	Group 1: 50-minute walk twice a week; Group 2: 60-90% 1RM weight training; Group 3: high resistance training and walking	Lumbar spine BMD	Muscular strength, bone metabolism biomarkers (e.g., osteocalcin)	No difference in BMD; increase in , muscular strength post-training
Singh, Schmitz, and Petit (2009)	Pre-menopausal *N* = 54 (30-50)	Strength training; 50-minute sessions twice a week for 15 weeks (supervised) and 39 weeks (unsupervised)	Total body BMD	1RM bench press and leg press	No significant change e in BMD after 9 months of strength training

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Table 5 continued

Study	Sample (age in years)	Intervention protocol	Bone health measures	Secondary measures	Results
Young et al. (2007)	Post-menopausal *N* = 45 (at least 5 years post menopause)	Group 1: 45-minute line dance per week; Group 2: line dance + progressively loaded squats 5 days a week; Group 3: line dance + loaded squats + foot stamps twice a day for 12 months	Proximal femur BMD	Muscular strength and balance	Significant reduction in lower-extremity bone loss, , improved muscular strength and balance

Table 6

Sedentary, Low-Intensity, and Moderate- to Vigorous-Intensity Activity Thresholds for Older Adults Using ActiGraph, activPAL, and 3D-PAR

	ActiGraph (activity counts/minute)	activPAL (minutes)	3D-PAR (categories)
Sedentary	< 100	Sitting or lying	1 and 2
Low intensity	100-1040	Standing or walking	3 to 9
Moderate-to-vigorous intensity	≥1041	n/a	5 to 9

Note. Threshold values are adapted from Gardiner et al. (2011), Hart et al. (2011), and Healy et al. (2008). Note that thresholds for moderate-to-vigorous intensity activities are different between younger adults and older adults using ActiGraph activity count measures. The activity threshold for moderate-to-vigorous intensity in adults is ≥1952 activity counts per minute. 3D-PAR = 3-Day Bouchard Physical Activity Record.

Appendix B

MTSU Institutional Review Board Approval

MIDDLE TENNESSEE STATE UNIVERSITY

October 12, 2012

Saori Ishikawa, Dr. Don Morgan
Department of Health and Human Performance
si2p@mtmail.mtsu.edu, Don.Morgan@mtsu.edu

Protocol Title: Impact of Reducing Sedentary Behaviors on Bone Health in Older Women

Protocol Number: 13-074

Dear Investigator(s),

The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an expedited review under the 45 CFR 46.110 Category 4.

Approval is granted for one (1) year from the date of this letter for 70 participants.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. **If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance (c/o Emily Born, Box 134) before they begin to work on the project.** Any change to the protocol must be submitted to the IRB before implementing this change.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918.

You will need to submit an end-of-project form to the Office of Compliance upon completion of your research located on the IRB website. Complete research means that you have finished collecting and analyzing data. **Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date.** Please allow time for review and requested revisions. Your study expires **October 12, 2013**.

Also, all research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Dr. Shelley Moore
IRB Committee Member

Appendix C

Informed Consent Document for Research: CHAPTER III

Middle Tennessee State University Institutional Review Board
Informed Consent Document for Research

MTSU
IRB Approved
Date: 10/12/2012

Principal Investigator: Saori Ishikawa
Study Title: Physical Activity, Sedentary Behavior, and Bone Health in Older Females (Study 1)
Institution: Middle Tennessee State University

Name of participant: ____ Age: __________

The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form.

Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. **Purpose of the study:**

   The purpose of the study is to examine the relationship between sedentary behavior, physical activity, and bone health in females 65 years of age or older who are postmenopausal.

2. **Description of procedures to be followed and approximate duration of the study:**

   During your visit to the MTSU exercise physiology laboratory, you will complete a written questionnaire describing your health history, physical activity, dietary habits, and quality of life. You will then be shown how to wear a light-weight physical activity monitoring device (ActiGraph) for a 7-day period beginning the day after the initial meeting. During this time, you will also complete a written sedentary behavior record. Once you've completed the physical activity recording and sedentary behavior monitoring, you will be asked to report back to the lab with the ActiGraph and the sedentary behavior record sheets. During your second visit after the 7-day activity monitoring, the investigator will measure your height and weight, and you will undergo a bone density scan to evaluate the strength of your back and hip. The researcher will ask you to take your jewelry off and will ask you to wear hospital scrubs (a 2-piece, lightweight cotton garment) prior to the bone assessment procedure. During the scan, you will lie motionless on a cushioned table while the machine scans the body part. Each scan (one at the hip and another at the lumbar spine) will take approximately 45 seconds.

3. **Expected costs:**
   There is no cost associated with your participation in this study.

4. **Description of the discomforts, inconveniences, and/or risks that can be reasonably expected as a result of participation in this study:**
   You will be exposed to a small radiation dose as a part of a 1-time bone scanning procedure. The radiation dose in a single scan is lower than what you would experience if you spent an entire day at the beach. It is recommended, though, that you do NOT participate in multiple investigations that utilize DXA, as exposure to ionizing radiation can have a cumulative effect.

   Inconveniences may include remembering to wear the activity monitoring device and recording of sedentary pursuits on each day of a week-long activity and sedentary behavior monitoring period.

Middle Tennessee State University Institutional Review Board
Informed Consent Document for Research

5. **Compensation in case of study-related injury:**
MTSU and the investigators conducting this study will not provide compensation in the case of study-related injury.

6. **Anticipated benefits from this study:**
Results from this study will potentially benefit science and humankind by contributing to the further understanding of the relationship between physical and sedentary activities and bone density in older women. Once the study period is completed, you will receive a feedback on your activity level and the results of your bone scan, which may help you to improve the awareness about your activity level and your current bone health.

7. **Alternative treatments available:**
There are no applicable alternative treatments that are available.

8. **Compensation for participation:**
There is no compensation for participation in this study.

9. **Circumstances under which the Principal Investigator may withdraw you from study participation:**
Any woman who is (or may be) pregnant will not be allowed to participate in a DXA assessment. This technology is approved for use with pregnant women, but we believe it is prudent to exclude them from bone scanning studies to eliminate unforeseen risks. You may also be asked to withdraw from the study if you move to another state, sustain a bone fracture, or become ill which may limit you from engaging in daily living activities.

10. **What happens if you choose to withdraw from study participation:**
There is no penalty for withdrawing from the study. In case you decide to withdraw from the study, you are asked to notify (in writing) the primary investigator of your intent to withdraw from the project. If you do withdraw from the study, any information that has been collected on you will be destroyed. A letter confirming your withdrawal will be sent to you indicating that you have been withdrawn from participation in our study.

11. **Contact Information.** If you should have any questions about this research study or possible injury, please feel free to contact the primary investigator, **Saori Ishikawa**, at **(774)240-7517** or her Faculty Advisor**, Dr. Don Morgan,** at **(615)898-5549.**

12. **Confidentiality.** All efforts, within reason, will be made to keep the personal information in your research record private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, and Federal Government Office for Human Research Protections, if you or someone else is in danger or if we are required to do so by law.

13. **<u>STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY</u>**
I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I freely and voluntarily choose to participate in this study.

__________________ ____
Date Signature of patient/volunteer

Middle Tennessee State University Institutional Review Board
Informed Consent Document for Research

Consent obtained by:

____________________ ______________________________________
Date Signature

____
Printed Name and Title

Appendix D

Informed Consent Document for Research: CHAPTER IV

Middle Tennessee State University Institutional Review Board
Informed Consent Document for Research

MTSU
IRB Approved
Date: 10/12/2012

Principal Investigator: Saori Ishikawa
Study Title: Feasibility of Reducing Sedentary Behavior in Older Females (Study 2)
Institution: Middle Tennessee State University

Name of participant: ____ Age: __________

The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form.

Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. **Purpose of the study:**
   The purpose of the study is to determine if it is possible to reduce sedentary behaviors in retired/non-employed older women (65 years of age or older) over a 1- to 2-month period.

2. **Description of procedures to be followed and approximate duration of the study:**
   You will meet with the primary investigator and complete a written questionnaire describing your health history to complete a health history questionnaire that will include your physical activity background, ability to engage in activities of daily living, and quality of life. After measuring your height and weight, you will be shown how to wear a light-weight physical activity monitoring device (ActiGraph) for a 7-day period beginning the day after the initial meeting. During this time, you will also complete a written sedentary behavior record. Once you've completed the physical activity and sedentary behavior monitoring, a research assistant will retrieve the ActiGraph and the sedentary behavior record sheets from you.

   Following this initial 7-day period, you will meet with the primary investigator to review your activity patterns and ways to reduce sedentary behavior for one month. Once the 1-month intervention period is completed, you will wear the ActiGraph and complete the sedentary behavior record for another 7-day period. You may again be asked to wear the device and complete the sedentary behavior record sheets after an additional 4-week period.

3. **Expected costs:**
   There is no cost associated with your participation in this study.

4. **Description of the discomforts, inconveniences, and/or risks that can be reasonably expected as a result of participation in this study:**
   Inconveniences may include remembering to wear the activity monitoring device and record sedentary behaviors.

5. **Compensation in case of study-related injury:**
   MTSU and the investigators conducting this study will not provide compensation in the case of study-related injury.

Middle Tennessee State University Institutional Review Board
Informed Consent Document for Research

6. **Anticipated benefits from this study:**
   Results from this study will potentially benefit the science and humankind by contributing to a better understanding of whether sedentary behavior patterns can be changed over the short-term in older women. Once the study is completed, you will also receive feedback regarding your sedentary behavior profile, which may help you become motivated to maintain a healthy lifestyle.

7. **Alternative treatments available:**
   There are no alternative treatments available.

8. **Compensation for participation:**
   There is no compensation for participation in this study.

9. **Circumstances under which the Principal Investigator may withdraw you from study participation:**
   You may be asked to withdraw from the study if you move to another state, become ill, or are suspected to be at risk of bone fracture, as this may limit you from engaging in daily living activities.

10. **What happens if you choose to withdraw from study participation:**
    There is no penalty for withdrawing from the study. In case you decide to withdraw from the study, please notify the primary investigator of your withdrawal in writing. If you withdraw from the study, any information related to you will be destroyed. A letter confirming your withdrawal will be sent to you indicating that your information has been withdrawn.

11. **Contact Information.** If you should have any questions about this research study or possible injury, please feel free to contact the primary investigator, **Saori Ishikawa**, at **(774)240-7517** or her Faculty Advisor, **Dr. Don Morgan,** at **(615)898-5549**.

12. **Confidentiality.** All efforts, within reason, will be made to keep the personal information in your research record private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, and Federal Government Office for Human Research Protections, if you or someone else is in danger or if we are required to do so by law.

13. **STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY**
    I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I freely and voluntarily choose to participate in this study.

__________________ _______________________________________
Date Signature of patient/volunteer

Consent obtained by:

__________________ _______________________________________
Date Signature

____
Printed Name and Title