

Sex Differences in the Relationship Between Light Physical Activity and
Metabolic Syndrome Risk Factors in Older Adults

By
© 2019
Genna Losinski
B.Sc., John Carroll University, 2013

Submitted to the graduate program in Psychology and the Graduate Faculty of the University of
Kansas in partial fulfillment of the requirements for the degree of Master of Arts.

Chair: Dr. Amber Watts, Ph.D.

Dr. Tamara Baker, Ph.D.

Dr. Sarah Kirk, Ph.D.

Date Defended: 12 November 2019

The thesis committee for Genna Losinski
certifies that this is the approved version of the following thesis:

**Sex Differences in the Relationship Between Light Physical Activity and
Metabolic Syndrome Risk Factors in Older Adults**

Chair: Dr. Amber Watts, Ph.D.

Date Accepted: 12 November 2019

Abstract

Light physical activity (LPA) is associated with improved metabolic syndrome (MetS) risk factors and research has demonstrated sex-associated differences in MetS and LPA. The present study explored differential associations between LPA and MetS risk factors. Participants were 107 older adults ($M = 74.78$ years, $SD = 6.29$) without cognitive impairment ($CDR = 0$) that wore accelerometers (Actigraph GT9X) during 7 consecutive days. Activity intensity was categorized as sedentary, light, and moderate based on Freedson Adult Vector Magnitude cutpoints. Participants completed a medical history that collected ATP-III defined MetS risk factors. Women had a higher mean moderate physical activity (28.81%) than men (22.86%, $t(86.02) = -3.51, p < .001$) and men had a higher mean sedentary behavior (27.98%) than women (24.27%), $t(87.80) = -2.12, p = .034$). However, light physical activity did not differ by sex ($t(81.05) = -1.49, p = .138$). Binomial logistic regressions demonstrated that the interaction between sex and time in light physical activity did not predict the presence of any of the metabolic syndrome risk factors, adjusting for age, education, Apolipoprotein E status, and medication use. The current sample was composed of highly educated ($M = 16.37$) primarily Caucasian and non-Hispanic older adults who were more active than average U.S. older adults. (light $M = 47.91\%$, moderate $M = 27.77\%$). These findings suggest that higher amounts of LPA may not demonstrate sex-associated differences in MetS risk factors. Future studies should explore these associations in a less active and less educated population of older adults.

Keywords: metabolic syndrome, light physical activity, older adults, accelerometry

Table of Contents

Introduction.....	1
Methods.....	9
Participants.....	9
Procedures.....	9
Measures	10
Data Analysis	13
Results.....	14
Participants.....	14
Physical Activity and Sex Differences	15
Metabolic Syndrome Risk Factors and Sex Differences	15
Binomial Logistic Regressions.	16
Discussion.....	17
Strengths and Limitations	21
Conclusion	24
References.....	26
Appendix.....	36

Introduction

Metabolic syndrome is a clinical condition characterized by a clustering of interrelated risk factors associated with type 2 diabetes and cardiovascular disease. Due to metabolic dysregulation and abnormal blood coagulation that are associated with the disease, individuals with metabolic syndrome are three times more likely to experience a myocardial infarction or a cerebrovascular event and five times as likely to develop diabetes (Stern 2004 & Ballantyne et al. 2016). Further, metabolic syndrome creates a proinflammatory state in the body which has been shown to increase the risk for depression (Viscogliosi et al., 2013) and may result in increased risk for cognitive impairment among older adults (Assuncao, Sudo, Drummond, De Felice, & Mattos, 2018). Age is the strongest predictor of diseases and chronic health conditions, including metabolic syndrome, thus it is important to study preventative interventions for metabolic syndrome tailored for older adults who are particularly vulnerable to these diseases.

Current guidelines emphasize lifestyle interventions as first-line strategies for preventing and managing metabolic syndrome, particularly increased physical activity. However, it is currently unclear what intensity level of physical activity is necessary to benefit health and remain realistic to implement in an older adult population. Light intensity physical activity has been associated with health benefits and may be more attainable in older adults. Several studies have shown sex-associated differences in physical activity types, patterns, and the benefits of physical activity on metabolic syndrome risk factors in older adults (Sun, Norman, & While 2013; Amagasa et al., 2017; Young-Shin, 2005; Watts, Walters, Hoffman, & Templin, 2016; Gando, Murakami, Kawakami, & Tanaka, 2014). Therefore, sex-associated differences should be considered when recommending physical activity for prevention and management of metabolic syndrome. As healthcare moves toward patient-centered care and individualized prevention and

treatment methods, it will be increasingly important to consider these sex-associated differences. Sex-associated differences will contribute to research in the practical implementation of physical activity as a preventative or interventional strategy customized for older adults. Significant sex-associated differences in the prevalence, clinical manifestations, and pathophysiology of metabolic syndrome have also been demonstrated but are often overlooked. Given the differences between men and women in health and physical activity at older ages, the proposed analysis is an effort to identify the specific sex-associated differences in the relationship between physical activity and risk factors of metabolic syndrome.

Clinically, metabolic syndrome diagnosis criteria may vary, but definitions focus on the core component features: abdominal obesity, hypertriglyceridemia, low HDL cholesterol concentrations, high blood pressure, and high-fasting glucose. For example, the most updated and commonly used diagnostic criteria defined by the Adult Treatment Panel III (ATP-III) report recommends the presence of three or more of the component features with sex-specific cut-off scores for diagnosis of metabolic syndrome. The International Diabetes Foundation (IDF) requires a waist circumference of 102 cm or more in men or 88 cm or more in women, plus two or more of the component features. Regardless of the definition, metabolic syndrome manifests clinically in a variety of ways dependent on the combination of individual components. Further, the greater the number of components, the higher the risk of developing subsequent diseases. The multiplicative nature of the components is not reflected in the definition or diagnostic criteria. Varying definitions and numerous combinations of the individual components has led to many generalized metabolic syndrome statements and misleading prevalence rates, potentially masking sex-associated differences. For example, there may be a distribution of the risk component combinations specific to sex, as discussed in detail below. However, these components are

categorized as one syndrome without further delineating the individual components. Further, confounding variables controlled for in studies such as levels of physical activity, a behavioral predictor, may influence the prevalence of specific metabolic syndrome components and these variables may also vary by sex. Examining metabolic syndrome by its individual components may reveal sex-associated differences and potential influence of behavior predictors.

Studies that have examined the patterns of clinical manifestations of metabolic syndrome have found variation by age and sex. Tsou and Chang (2013) conducted a cross-sectional survey among Taiwanese older adults and reported substantial variations in the individual components of metabolic syndrome according to sex. Most notably, women diagnosed with metabolic syndrome demonstrated significantly higher waist circumferences and lipid levels compared to men. Similar sex-related waist circumference patterns have been found among Chinese adults and American older adults (Gu, Reynolds, Wu, Whelton, & He, 2005; Kuk & Arden, 2010). Additionally, the Kuk & Arden (2010) study found that high levels of glucose and low HDL cholesterol levels were more strongly associated with mortality in women, but this relationship was not found in men. Abdominal obesity has also been identified as the most common metabolic syndrome component in women across the lifespan (Ford, Giles, & Dietz, 2002). These studies collectively suggest abdominal obesity and lipid levels may have a greater relative importance in the development of metabolic syndrome in women than men.

The prevalence of metabolic syndrome is increasing in the United States, mainly driven by the obesity epidemic (Grundy, 2008). Epidemiological studies have demonstrated slight differences in prevalence patterns by age and sex over the lifetime. Among older adults, Kuk and Arden (2010) examined both the individual components and different combinations and found that 4 of the 31 combinations of metabolic syndrome in men and women were not equally

prevalent (Kuk & Arden, 2010). Another study found that for men, the prevalence of metabolic syndrome increased with age through the sixth decade of life and seventh decade for women (Park et al., 2003).

The most prominent underlying risk factors for metabolic syndrome in general are abdominal obesity and insulin resistance (Lemiex et al., 2000; Park et al., 2003; Carr et al., 2004; Reaven, 1988; Ferrannini, Haffner, Mitchell, & Stern, 1991). An important behavioral predictor of these symptoms is physical inactivity. With increasing age comes a lifetime accumulation of risk factors associated with metabolic syndrome, most notably increasing rates of physical inactivity. Physical inactivity over time may lead to abdominal obesity, insulin resistance and other health consequences related to metabolic syndrome (Edwards & Loprinzi, 2018). Current American Heart Association guidelines emphasize lifestyle interventions, such as diet and increased physical activity as first line strategies for preventing and managing metabolic syndrome across age, sex, and ethnicities, without taking these outlined sex-associated and age-related differences into consideration (Grundy et al., 2005).

Weight distribution during aging differs between men and women. For men, adipose tissue accrues in the trunk and abdomen as compared to the hips and thighs of women. Men typically carry two-fold higher amounts of visceral fat, as compared to premenopausal women. Visceral fat accumulation is related to cardiovascular disease and metabolic disease compared to other types of fat (Chodzko-Zajko et al. 2009). Studies that have compared similar total body weight loss between men and women have demonstrated that men lose more visceral fat, resulting in greater improvements in their metabolic components, where women's metabolic components do not improve from the same amount of weight loss (Vissers et al., 2013).

The suggested therapeutic goal and recommendations for clinical management of metabolic syndrome focuses on moderate to vigorous physical activity, driven by the dose-response relationship of physical activity (Grundy et al., 2005, Lakka & Laaksonen, 2007; Yang et al., 2008; Rennie, McCarthy, Yazdgerdi, Marmot, & Brunner, 2003; Lee & Paffenbarger, 2000; Jeon, Lokken, Hu, & Van Dam, 2007; Janssen & Ross, 2012). The Centers for Disease Control and Prevention guidelines recommends older adults engage in 150 minutes of moderate intensity aerobic exercise or 75 minutes of vigorous intensity aerobic exercise every week and muscle-strengthening activities on two or more days a week that work all major muscle groups. Despite these recommendations, recent research suggests over 60% of older adults remain sedentary, drastically increasing their risk for metabolic syndrome (Harvey, Chastin, & Skelton, 2013). Therefore, there is a need to focus on ways to make physical activity more feasible for older adults.

To help increase physical activity and avoid sedentary behavior, Manns et al. (2012) discussed a “whole of day” approach to physical activity promotion also known as “lifestyle physical activity.” This approach advocates for not only an increase in moderate-to-vigorous physical activity, but also for increasing lifestyle activity which includes leisure activities and light-intensity physical activities. Light physical activity is typically unstructured, such as housework or yardwork activities including gardening, mowing the lawn, sweeping, mopping, and window-washing. Casual walking, stretching, light-weight training, dancing slowly, and leisurely sports are also examples of light physical activity. In fact, recent research suggests that light physical activities accounts for a significant portion of total energy expenditure in older adults (Loprinzi, 2015). Loprinzi (2015) found that in their sample of nearly 1,500 adults age 65 and over, 48% of participants engaged in more than 300 minutes per week of light physical

activities. However, unlike moderate-to-vigorous physical activity, there are no guidelines for recommendations for light physical activity despite the emerging evidence that indicates important sex-differentiated health benefits.

The Self Determination Theory (SDT) allows exploration of physical activity motivation as a way to get more people to engage in physical activity (Deci & Ryan, 1985). Derived from the humanistic perspective, the SDT believes individuals are not necessarily motivated by rewards, but rather sees intrinsic motivation as a more powerful and effective way to encourage individuals to engage in certain behaviors. The SDT is centered around the idea that individuals have three basic needs: competence, autonomy, and relatedness. Once these needs are fulfilled, an individual will feel more intrinsically motivated to engage in a targeted behavior that has value to them. Previous research has demonstrated a relationship between the SDT and motivation to engage in moderate to vigorous physical activity in older adults (Dacey, Baltzell, & Zaichkowsky, 2008; Teixeira, Carraça, Markland, Silva, & Ryan, 2012). However, the SDT has not been applied to light-intensity physical activity among older adults. Light-intensity physical activity and its potential health benefits and sex-associated differences may have the capacity to fulfill these three basic needs in an attempt to motivate older adults to engage in more movement and ultimately feel motivated and capable of incorporating more moderate to vigorous physical activity into their everyday lives.

Some research suggests sex-associated differences in the types and patterns of various levels of physical activity. Further, physical activity patterns such as time of day and type of activity, change with age-related changes such as decrease in mobility and cognitive decline. Sun et al. (2013) measured physical activity engagement by both subjective and objective criteria in older adults and concluded that women were less likely than men to achieve regular physical

activity guidelines. However, evidence suggests women engage in more light physical activity than men (Amagasa. et al, 2017; Healy et al., 2007; Hawkins, Gabriel, Conroy, Cooper, & Sutton-Tyrrell, 2013). Self-reported questionnaires revealed older adult women were more likely to engage in household activities compared to men. In addition, women reported more personal and environmental factors that created poor conditions for physical activity engagement (Young-Shin, 2005). Studies examining sex-associated differences within physical activity patterns have found that women are significantly less variable in activity level throughout the day (Watts et al., 2016).

Although existing research is contradictory and inconclusive, there are studies that have shown health benefits to light physical activity and many relate to the numerous metabolic syndrome components. Amagasa et al. (2018) systematically reviewed epidemiological studies reporting that objectively measured light physical activity was inversely associated with all-cause mortality risk and was favorably associated with waist circumference, triglyceride levels, and insulin levels in older adults. A systematic review with a meta-analysis of observational and experimental studies (Chastin et al., 2018) quantified the effect of time spent in light physical activity in adults examining the effect of bouts of light physical activity throughout the day. His review found that short but frequent bouts of light physical activity reduced postprandial glucose levels and insulin levels compared with continuous sitting behavior. Chastin et al. (2018) also found that 12-week light physical activity interventions reduced adiposity, improved blood pressure and improved lipidemia. When considering optimal amount of light physical activity necessary to elicit a beneficial effect in older adults, Loprinzi (2015) found that engaging in 300 minutes per week of light physical activity was associated with lower body mass index, waist circumference, and insulin resistance. All three reviews agreed that light physical activity was

beneficial for waist circumference and insulin levels but had mixed results for body mass index, triglycerides, glucose levels, HDL cholesterol and all-cause mortality. However, very few of the studies observing the relationship between light physical activity and metabolic syndrome stratified the participants by sex and considered sex-associated differences. Individual studies such as Gando et al. (2014) found that objectively measured light physical activity was inversely associated with insulin resistance in older Japanese women more strongly than in men.

Research has demonstrated sex-associated differences in prevalence, clinical expression, and pathophysiology of metabolic syndrome throughout the lifespan. An increased amount of light physical activity is associated with improved individual components of metabolic syndrome in older adults. However, whether this relationship varies by sex has not yet been examined. To develop effective physical activity interventions among older adults, potential sex-associated differences within the benefit of light physical activity should be addressed. Yet, no published studies have examined the potential differential benefit of light physical activity between men and women in individual components of metabolic syndrome in older adults.

The current proposal aims to explore the question of whether objectively measured total time spent in light physical activity in a free-living environment predicts individual metabolic syndrome risk factors in older adults and whether this relationship differs by sex. Based on the sex-associated differences demonstrated in metabolic syndrome during the lifespan, the present study predicts a sex-associated difference in the relationship between light physical activity and metabolic syndrome risk factors. Because of the established physical activity dose-response relationship, we predicted that higher amounts of light physical activity engagement would be associated with fewer metabolic syndrome risk factor than lower amounts of light physical activity. We predicted that this association would be stronger in women than in men (Loprinzi,

2015; Chastin et al., 2018; Amagasa et al., 2018; Tsou & Chang, 2013; Gu et al., 2005; Kuk & Arden, 2010; Ford et al., 2002).

Methods

The present study is a secondary analysis of an ongoing study which measures physical activity and sleep with wrist worn activity monitors (accelerometers) in participants of the research registry at the University of Kansas Alzheimer's Disease Center (KU-ADC). Annual requirements of the KU-ADC Registry include cognitive testing and a comprehensive clinical examination conducted as part of a longitudinal observational study.

Participants

The KU-ADC Registry is a large registry of older adults 60 years and older with well-characterized Alzheimer's disease or without cognitive impairment. Participants of the Registry gave consent to be contacted for future studies. Experienced study clinician trained in dementia assessment determined the health status of participants and determined a consensus diagnosis of cognitive status. As part of this process, the KU-ADC Registry excludes individuals with clinically significant depressive symptoms, abnormalities in B12, Rapid Plasma Reagin (RPR), or thyroid function, significant visual or auditory impairment, and systemic illness that may impair completion of the KU-ADC Registry evaluations. Participants from the KU-ADC Registry above the age of 60 and without evidence of cognitive decline (Clinical Dementia Rating (CDR) = 0) were included in the analyses.

Procedures

The study was approved by the University of Kansas Medical Center Human Subjects Committee. At the KU-ADC Registry annual study visit, participants were recruited for the additional physical activity and sleep monitoring sub-study. Interested participants provided

written informed consent and agreed to wear a wrist worn accelerometer for the following seven days in their free-living environment. Participants were provided a pre-stamped and addressed envelope to send the accelerometer back to the research team after seven days of data collection. Upon receiving the envelope, accelerometer data were downloaded and processed according to a standardized operating procedure. Information regarding age, sex, race, years of education, medical history (diabetes, hypertension, hypercholesterolemia and related medication use), clinical lab results (APOE genotyping), body mass index (BMI), and waist circumference (WC) were obtained from the annual KU-ADC registry study visit for each participant.

Measures

Accelerometry. Accelerometry was used to objectively measure the total daily waking hours spent in light physical activity. Accelerometry has been used as a valid objective measure of physical activity that is noninvasive with minimal participant burden (Kulinski et al., 2014). Participants wore an accelerometer (ActiGraph, LLC, GT9X, Pensacola, FL) on their non-dominant wrist for seven days. The accelerometer is waterproof, therefore participants were instructed to wear the accelerometer 24 hours a day including during showering, bathing, or swimming to accurately measure physical activity and sleep behaviors.

ActiLife software version 6.13.2 was used to analyze the data (Actigraph, LLC, GT9X, Pensacola, FL). The Choi Wear Time Validation algorithm combined with self-reported wear logs was used to determine time periods where participants were asleep or did not wear the accelerometer (Choi, Liu, Matthews, & Buchowski, 2011). Consistent with the literature of objective measurement of light physical activity in older adults, the Freedson Vector Magnitude algorithm was used to estimate activity cut points (Freedson, Melanson, & Sirard, 1998; Sasaki, John, & Freedson, 2011) that are used to categorize activity by intensity level (e.g., sedentary,

light, moderate, vigorous). Sedentary behavior was defined as 0-99 counts per minute, light intensity 100-2689 counts per minute, moderate intensity 2690-6166 counts per minutes, and vigorous intensity 6167-9642 counts per minute.

The proportion of total daily waking hours spent in sedentary, light, moderate, and vigorous physical activity that occurred during valid wear time days was calculated. A valid full day (24 hours) of ActiGraph data wear time validation was defined as at least 10 hours of wear time per day, which is equivalent to 600 minutes. To be included in this analysis, a participant must have had at least 4 valid days of ActiGraph data and data extending beyond 7 valid days was excluded. For each participant, the percentage of time spent in each intensity each day (sedentary, light, moderate, vigorous) was added together from each valid day and divided by the total number of valid days to calculate the average amount of physical activity behavior in each individual intensity level.

Metabolic Syndrome Risk Factors. The presence of the following metabolic syndrome risk factors defined using the ATP-III criteria were included as outcome measures: diabetes, hypertension, hypercholesterolemia, hypertriglyceridemia, body mass index greater than 30 (CDC, 2017), and waist circumference greater than 40 inches for men and greater than 35 inches for women (National Cholesterol Education Program, 2002). These outcomes are consistent with the core component features of metabolic syndrome and have been shown to reflect sex-associated differences in past literature. The presence of diabetes, hypertension, and hypercholesteremia were collected from a yes/no question listed on the medical history form that was completed during an interview with a physician at the KU-ADC Registry yearly visit. The presence of hypertriglyceridemia was determined by use of high triglycerides medication derived from a yes/no question listed on the medical history form. If a participant reported taking

medication for high triglycerides, it was assumed that the participant had a history of high triglycerides. Average waist circumference was calculated from three collected measurements at the KU-ADC Registry yearly visit and then dichotomized (above or below cutoff) using the ATP-III sex specific criteria. The ATP-III definition of diagnosing metabolic syndrome with the presence of 3 or more risk factors was used to define a diagnosis of metabolic syndrome (CDC, 2017).

Moderator. Self-reported sex (male or female) was used to observe whether sex affects the strength of the relationship between amount of light physical activity and the presence of individual metabolic syndrome risk factor outcomes.

Covariates. Age and education have been identified in the literature as important covariates for both physical activity and metabolic syndrome and were accounted for in analyses. Education was used as an indicator of social position and socioeconomic status (SES). Studies have shown that lower SES is associated with less regular physical activity and more adverse health outcomes in older adults (Ball, Carver, Downing, Jackson, & O'Rourke, 2015; O'Donoghue et al., 2018). Research has established sex-associated differences in the relationship between SES and metabolic syndrome such that women from lower SES tend to have a higher prevalence of metabolic syndrome yet this relationship was not found in men (Santos, Ebrahim, & Barros, 2008). Apolipoprotein E (APOE) status is one of the most researched risk factors for Alzheimer's disease. Recent studies have demonstrated sex-associated differences among the gene expression indicating more detrimental effects for women. Females that carry the APOE epsilon 4 gene ($\epsilon 4$) have been shown to have a 1.5x higher risk for Alzheimer's disease and more amyloid plaques and neurofibrillary tangles compared to males (Barha & Liu-Ambrose, 2018). Therefore, APOE status was included to observe the possible predictive role of sex-associated

differences and APOE status on light physical activity and metabolic syndrome biomarkers. APOE status was determined by restriction enzyme isotyping. The yes/no indication of hypertension medication use and hypercholesteremia medication use as reported in the KU-ADC Registry medical history were also included as covariates in the current analysis.

Data Analysis

Physical Activity Intensity Comparison. To examine sex differences in physical activity intensity, independent sample t-tests were conducted using percentage of total amount of daily activity spent in sedentary, light, moderate, and vigorous physical activity and self-reported sex.

Individual Metabolic Syndrome Risk Factor Comparison. To examine sex differences in the individual metabolic syndrome risk factors, individual chi square analyses were conducted using the presence of diabetes, hypertension, hypercholesterolemia, body mass index greater than 30, and waist circumference greater than 40 inches for men and greater than 35 inches for women and self-reported sex. Chi square analyses also examined sex differences in the percentage of participants that met the ATP-III criteria for metabolic syndrome.

Binomial Logistic Regressions. To examine sex-associated differences in the relationship between total amount of daily activity spent in light physical activity and the dichotomous categorical presence of individual metabolic syndrome risk factors (yes/no), we conducted a logistic regression with an interaction between sex and amount of light physical activity. This analysis investigated whether or not the amount of light physical activity predicted the probability of the presence of individual metabolic syndrome risk factors differently between men and women. Age, education, APOE, and hypertension and hypercholesteremia medication use (yes/no) were included in the model as covariates. Potential type 1 errors from multiple

testing were adjusted for with the Benjamini-Hochberg method with the critical value for a false discovery rate set at 0.25 (Benjamini & Hochberg, 1995). The full logit model with the interaction term took the following form:

$$\ln[y / (1 - y)] = b_0 + b_1*(\% \text{ light physical activity}) + b_2*(\text{sex}) + b_3*(\% \text{ light physical activity})*(\text{sex}) + b_4 - b_8*(\text{covariates})$$

Results

Participants

As presented in Table 1 and Table 2, participants were 35 men and 72 women aged 63 to 91 years. The sample was highly educated, and education was significantly higher for men than for women. The majority of the sample was Caucasian and non-Hispanic. Participants included in this analysis were without evidence of cognitive decline (CDR = 0).

The original sample had 112 participants. We excluded participants for the following reasons: primary diagnosis of “impaired” ($n = 2$), missing data on important outcome variables ($n = 2$), and 406 days between medical history and accelerometry ($n = 1$). One participant had missing height data and therefore was excluded from the BMI logistic regression model. Three participants did not have APOE status information available and were only excluded from the analyses when APOE status was required.

Accelerometer data included in the current analysis was collected between September 2015 and February 2019. Within this timeframe, 26 participants had two sets of ActiGraph data that were collected at different timepoints. Only the most recent data collection was included in this analysis. All participants had accelerometer data recorded within two months of their medical history collection (range: 0-56 days, $Mdn = 0.00$, $M = 0.74$, $SD = 5.47$).

Physical Activity and Sex Differences

Participants in the current sample varied by total valid days of accelerometer wear time which ranged from four to seven days. Therefore, the percentage of daily waking hours spent in various physical activity intensities were calculated based on the varying number of total days of wear. As presented in Table 2, the majority of total daily waking hours was spent engaging in light physical activity and moderate physical activity. Only two participants in this sample engaged in vigorous physical activity therefore the vigorous physical activity intensity was excluded from this analysis.

An independent samples t-test indicated that the percentage of time spent in sedentary behavior was significantly higher for men than for women. No differences in percentage of time spent in light physical activity between men and women were observed. However, the percentage of time spent in moderate intensity physical activity differed significantly between men and women suggesting that women engaged in more moderate physical activity (Table 2).

Metabolic Syndrome Risk Factors and Sex Differences

As presented in Table 3, 24.5% of participants in the sample met criteria for the BMI risk factor and relatively few participants reported a diabetes diagnosis. However, half of the sample met criteria for the waist circumference risk factor and reported a diagnosis of hypertension. Over half of the participants reported hypertriglyceridemia and hypercholesteremia. Individual chi-square tests were conducted to examine sex differences among each individual metabolic syndrome risk factor (Table 3). A sex difference was demonstrated for hypertriglyceridemia such that significantly more men reported hypertriglyceridemia than women. When examining the sex differences among the remaining individual metabolic syndrome risk factors, none of these frequencies were significantly different.

According to the metabolic syndrome ATP-III definition of diagnosing metabolic syndrome with the presence of 3 or more risk factors, 36% of the sample met the ATP-III criteria for metabolic syndrome. The percentage of participants that met criteria for metabolic syndrome did not differ by sex (Table 3).

Binomial Logistic Regressions.

Six individual logistic regression models were conducted to examine whether the amount of light physical activity predicted the probability of independent metabolic risk factors: waist circumference, BMI, diabetes, hypertension, hypercholesteremia, and hypertriglyceridemia. We included an interaction term between sex and amount of light physical activity to determine whether this relationship differed between men and women. All of the models controlled for percent time spent in light physical activity, education, age, sex, hypertension medication use, hypercholesteremia medication use, and APOE status. Results from the logistic regressions were corrected with the Benjamini-Hochberg critical value for a false discovery rate of 0.25, as reported in Table 4.

Light Physical Activity and Sex Differences. We did not find sex differences among the relationship between the six individual metabolic syndrome risk factors and the total percentage of light physical activity in this sample of older adults (Table 4). For both men and women, the relationship between total amount of light physical activity and the predicted probability of having the waist circumference risk factor was approaching significance. For a one unit increase in light physical activity engagement, the odds of having the waist circumference risk factor increased by a factor of 1.06 (Table 4). For the remaining individual metabolic syndrome risk factors including BMI, diabetes, hypertension, hypercholesterolemia and hypertriglyceridemia,

the total percentage of time spent engaging in light physical activity was not a predictor of their presence for this sample of older adults (Table 4).

Metabolic Risk Factors and Medication Use. Hypertension medication use was a significant predictor of the hypertension risk factor as well as the waist circumference and BMI risk factors. These results suggest that taking hypertension medication increased the predicted probability of having the waist circumference risk factor by 72% and increased the predicted probability of having the BMI risk factor by 83% (Table 4).

Metabolic Risk Factors and APOE Status. APOE ϵ 4 carrier status was not significantly related to any of the risk outcomes: BMI, waist circumference, diabetes, hypertension, hypercholesterolemia, and hypertriglyceridemia and this relationship did not vary by sex in this sample of older adults.

Discussion

The purpose of this study was to determine whether sex influences the association between light physical activity and metabolic risk factors among older adults. In our sample of highly active older adults with an average prevalence rate of metabolic symptoms, light physical activity was not predictive of individual metabolic risk factors and this relationship did not differ between men and women. However, we did observe sex differences in rates of physical activity intensities and distribution of metabolic risk factors. For both men and women, this sample of older adults was highly active in both light-intensity physical activity and moderate-intensity physical activity compared to prevalence rates reported in the physical activity and older adult literature (Harvey et al., 2013; Loprinzi, 2015; Evanson, Buchner, & Morland, 2012). One third of our sample met criteria for metabolic syndrome, which is representative of the prevalence of

metabolic syndrome among older adults in the United States (National Center for Health Statistics, Division of Health Interview Statistics, 2012).

These results are consistent with findings from the Batacan et al. (2015) systematic review of intervention studies that found that light physical activity was not associated with metabolic risk factors in individuals who engage in higher amounts of moderate physical activity. However, results from the review indicated that light physical activity interventions were able to predict improvement for some risk factors in physically inactive older adults with a medical condition. Future studies should explore whether the effect of light physical activity on metabolic syndrome risk factors may look different in a less active population and whether sex differences may exist in these relationships. In fact, the motivation behind Manns et al. (2012) “lifestyle physical activity” approach was specifically designed to promote physical activity among those who are physically inactive. From the SDT perspective, an inactive population may be more intrinsically motivated to engage in light physical activities compared to moderate physical activities. Light physical activities may allow free will to choose from a broader range of activities that may bring meaning to an inactive individual as compared to interventional exercise programs. Further, if an older adult knows that engaging in light physical activity may lead to health benefits specific to their sex, it may fulfill a need for competence and the ability to do something efficiently. Light physical activity also has the capability to involve social and community engagement.

The individual metabolic syndrome risk factors were not equally prevalent among our older adult population (Table 3). These findings may explain why we did not observe an effect of light physical activity on predicting prevalence of metabolic syndrome risk factors. Instead, our sample was primarily composed of individuals equally meeting criteria for hypertriglyceridemia,

hypercholesteremia, and hypertension. Diabetes and large waist circumference were least prevalent. These results contradict a recent analysis of the Third National Health and Nutrition Survey (Kuk & Arden, 2010) that noted equal prevalence of all metabolic syndrome risk factors among older adults. The combined findings of previous research have demonstrated support for a benefit of light physical activity for insulin and waist circumference (Amagasa et al. 2018; Chastin et al. 2018; Loprinzi, 2015). This may help explain why we did not see a benefit of physical activity for these risk factors in our sample that lacked a higher rate of these two particular risk factors.

Within our sample, men had a higher prevalence of the hypertriglyceridemia risk factor compared to women. Men also engaged in more sedentary behavior and less moderate-intensity physical activity than women. These results are similar to research suggesting sedentary behavior is associated with more negative health outcomes, including a higher risk for metabolic syndrome and its risk factors (Figueiro et al., 2019). These findings also suggest women who, on average, engaged in higher amounts of moderate physical activity and lower amounts of sedentary behavior, had a lower rate of hypertriglyceridemia. This is consistent with studies that have found that spending less time in sedentary behavior and more time in moderate physical activity is directly linked to healthier levels of HDL cholesterol and triglycerides (Crichton & Alkerwi, 2015). Some studies have suggested sex differences in this relationship between sedentary behavior and negative health outcomes, including metabolic syndrome risk factors (Sisson et al. 2009). Future studies should delineate whether sex-associated health outcome changes may be due to less sedentary behavior or increased engagement in light physical activity.

In the present study, age did not predict the presence of metabolic syndrome risk factors. For highly active and educated Caucasian older adults between the ages of 63-91, there was an equal risk for having or not having the individual metabolic risk factors. These findings are consistent with research that says prevalence of metabolic syndrome are the same between men and women above age 65 (Mozumdar & Liguori, 2011). Although sex-associated differences exist during aging such as weight distribution, by age 70 these differences may create similar metabolic syndrome susceptible presentations in men and women. This sample is likely older than the age at which these changes occur and that may explain why other sex associated differences were not found. Further, five of the six metabolic risk factors were found to be equally prevalent between both sexes in our older adult sample, which remains consistent with previous research (Kuk & Arden, 2010). This area of research has suggested that more definitive sex-associated differences may be more prominent earlier in the aging process, particular during young adult and middle adult ages (Pradhan, 2014). Future studies may seek to explore whether light physical activity may prove to be an advantageous intervention for women or men in different segments of older adult age groups.

The average education for both men and women in our sample was a bachelor's degree or above. According to the U.S. Census Bureau as of 2018, 29% of older adults have a bachelor's degree (U.S. Census Bureau, 2018). Therefore, our sample was highly educated compared to older adults in the United States. Even accounting for these elevated education levels, lower education predicted the higher likelihood of the BMI and hypertension risk factors. These results suggest that these risk factors are perhaps more sensitive to socioeconomic implications as compared to the waist circumference, diabetes, hypercholesterolemia, or hypertriglyceridemia risk factors. Men in our sample were more educated than women. Taken together with the

difference in physical activity intensity engagement, these results are similar to research regarding sex differences in physical activity determinants. In particular, these results coincide with studies that have found that older adult men's physical activity level is associated with education and health status whereas women's physical activity levels are more associated with marital status and living arrangements (Chipperfield, Newall, Chuchmach, Swift, & Haynes, 2008; Yue et al., 2007).

Our results may suggest typical clusters of metabolic risk factors in this sample of highly active and educated Caucasian older adults. In this sample, the waist circumference and hypertension risk factors were present more often clustered together as well as the grouping of the BMI and hypertension risk factors. These results are consistent with literature that reports that obesity typically presents first which contributes to the development of sequential risk factors, especially insulin resistance (Park et al. 2008) and the prevalence of metabolic syndrome risk factors increases with obesity (Weiss et al., 2004). Further, the presence of multiple metabolic syndrome risk factors is multiplicative when considering risk for subsequent disease. It may be of interest for future studies to examine the effects of light physical activity and its potential relationship with the different amount and various clustering combinations of risk factors rather than each risk factor individually.

Strengths and Limitations

It is important to consider the strengths and limitations of the current study in context of the validity and generalizability of our findings. The observational nature of the current study allowed for a better understanding of physical activity behaviors among older adults. Older adults were engaging in physical activity in their free-living environment, meaning results were collected from a naturalistic setting rather than in an artificially contrived laboratory setting. A

strength of the current study was the use of accelerometry to measure the amount of various intensities of physical activity engagement and sedentary behavior as opposed to self-reported physical activity questionnaires, which have numerous well documented limitations. When measuring light physical activity, accelerometry is able to detect light movements that are typically experienced in everyday life and not normally reported as physical activity in self-report questionnaires (Colbert, Matthews, Havighurst, & Schoeller, 2011).

There are also limitations with the use of accelerometry. In the current study, average daily percent time spent in sedentary, light, and moderate-intensity physical activity was calculated based on activity counts with an accelerometer worn on a participant's non-dominant wrist. Physical activity measured by activity counts have been found to be more accurately measured using accelerometers worn on the hip as opposed to the wrist-worn (Toth et al., 2018). In addition, the current study did not collect a diary of physical activity therefore a general limitation of accelerometry measurement without a diary is that the type of behavior being recorded is not known. Choosing to measure physical activity engagement using the average of total percentage of time spent in various intensity levels over a week can be problematic when interpreting results. Average percentage measurements do not account for physical activity variability that may occur within a day or over a week. Studies have found that for individuals that report the same average of total percentage of time spent in physical activity, the patterns of their physical activity may look completely different (Watts et al., 2016). Future studies may consider measuring bouts of behavior as recent research have found bouts of physical activity and sedentary behavior as being predictive of disease, including metabolic syndrome (Chastin, Egerton, Leask, & Stamatakis, 2015).

Another limitation of the current study was the binomial (yes/no) categorization of metabolic syndrome risk factors. Blood sample biomarkers would have provided a more accurate representation of the severity of the hypertriglyceridemia (triglyceride levels), hypercholesteremia (HDL cholesterol levels) and diabetes (fasting insulin and glucose levels) metabolic syndrome risk factors. Further, diabetes is a well-known outcome of metabolic syndrome, however diabetes was used as a risk factor for metabolic syndrome in the current analysis. Because insulin and glucose levels were not collected, many participants in the current analysis without a diabetes diagnosis may still have had increased glucose and insulin levels that were therefore not accounted for in our analysis.

Important considerations regarding the recruitment techniques limits the current study by selection bias. Participants in the current analysis were recruited from a voluntary registry. Individuals from a higher SES are more likely to volunteer for research. Another problem with the sampling methods of the current study is that individuals who are more active are more likely to agree to participate in a study that requires wearing a device that monitors physical activity levels. The preponderance of Caucasian, educated, and highly active status of the older adult sample diminishes the external validity of the results of the current study. Further, it should be noted the imbalance between sample size of men and women in the current sample and relatively small sample size of men that may have limited the analysis of sex-associated differences.

Another criticism of the current study is the cross-sectional design, therefore directionality of results cannot be determined. Light physical activity engagement may be indicative of less probability of metabolic syndrome risk factors or presence of metabolic syndrome risk factors may influence amount of light physical activity engagement. Future intervention studies examining light physical activity, metabolic syndrome, and sex-associated

differences may examine directionality more appropriately. Further, cross sectional studies examining health outcomes and behaviors should control for life course history. Health outcomes and behaviors are cumulative therefore analyses examining health outcomes should be controlling for health and physical activity engagement over a lifetime in an attempt to examine potential effects in later life.

The current study is limited by its lack of control for other well-established modifiable lifestyle behaviors, health conditions, socioeconomic considerations, and psychological factors strongly associated with metabolic syndrome and physical activity among older adults. Research has demonstrated associations with the prevalence of metabolic syndrome and engagement in physical activity with behaviors such as smoking and diet as well as health conditions such as chronic pain (Lin, Hsiao, & Chen, 2009; Rezanian, Solivan, Rezai, & Roos, 2011; Babio et al, 2014). Controlling for socioeconomic status using primarily education, the current analysis did not consider any other social determinants of health or examine sex-associated differences among occupation and household income levels that have been found to have important implications when considering metabolic syndrome prevalence and physical activity engagement (Lin et al., 2009; Wu & Porell, 2000). The role of psychological factors and well-being, which affect both the prevalence of metabolic syndrome risk factors and physical activity engagement, were also not addressed in the current study (Loprinzi, 2015; Almedia, Calver, Jamrozik, Hankey, & Flicker, 2009; Goldbacher & Matthews, 2007).

Conclusion

To our knowledge, this is the first study to investigate accelerometer-measured light physical activity and sex differences among metabolic syndrome risk factors in older adults.

We did not find an association between light physical activity and metabolic risk factors. Our study contained a sample of highly educated primarily Caucasian older adults, who are more active than the average older adult in the United States. Thus, our findings may not generalize to the majority of older adults. The current study and its preliminary findings function as an exploratory step in studying the relationship between light physical activity, metabolic syndrome risk factors, and sex-associated differences. More prospective experimental and interventional studies, conducted with diverse samples and controlling for more psychosocial and environmental factors from a life course perspective, are needed. Continued research examining the relationship between light physical activity, health benefits, and sex-associated differences is warranted, especially as successful interventions for getting older adults motivated to engage in more physical activity are lacking.

References

- 2018 Physical Activity Guidelines Advisory Committee. *2018 Physical Activity Guidelines Advisory Committee Scientific Report*. Washington, DC: US Dept of Health and Human Services; 2018. https://health.gov/paguidelines/secondedition/pdf/pag_advisory_committee_report.pdf.
- Almedia, O., Calver, J., Jamrozik, K., Hankey, G., & Flicker, L. (2009). Obesity and metabolic syndrome increase the risk of incident depression in older men: the health in men study. *The American Journal of Geriatric Psychiatry, 17*(10), 889-898.
- Amagasa S, Fukushima N, Kikuchi H, Takamiya T, Oka K, & Inoue S. (2017). Light and sporadic physical activity overlooked by current guidelines makes older women more active than older men. *International Journal of Behavior, Nutrition and Physical Activity, 14*:59.
- Amagasa, S., Machida, M., Fukushima, N., Kikuchi, H., Takamiya, T., Odagiri, Y., & Inoue, S. (2018). Is objectively measured light-intensity physical activity associated with health outcomes after adjustment for moderate-to-vigorous physical activity in adults? A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 15*:65.
- Assuncao, N., Sudo, F., Drummond, C., De Felice, F., & Mattos, P. (2018). Metabolic syndrome and cognitive decline in the elderly: A systematic review. *PLoS One, 23*(3), doi: 10.1371/journal.pone.0194990.
- Babio, N., Toledo, E., Estruch, R., Ros, E., Martinez-Gonzalez, M. Castaner, O., ... Salas-Salvado, J. (2014). Mediterranean diets and metabolic syndrome status in the

- PREDIMED randomized trial, *Canadian Medical Associations Journal*, 186(17), E649-E657.
- Ball, K., Carver, A., Downing, K., Jackson, M., & O'Rourke, K. (2015). Addressing the social determinants of inequities in physical activity and sedentary behaviors. *Health Promotion International*, 30(2), ii8-ii9.
- Ballantyne, C., Hoogeveen, R., McNeill, A., Heiss, G., Schmidt, M., Duncan, B., & Pankow, J. (2016). Metabolic syndrome risk for cardiovascular disease and diabetes in the ARIC study. *International Study of Obesity*, 32(2): S21-S24.
- Barha, C., & Liu-Ambrose, T. (2018). Exercise and the Aging Brain; Considerations for Sex Differences. *Brain Plasticity*, 4(1), 53-63.
- Batacan, R., Duncan, M., Dalbo, V., Tucker, P., & Fenning, A. (2015). Effects of light intensity activity on CVD risk factors: A systematic review of intervention studies. *BioMed Research International*, Doi: 10.1155/2015/596367.
- Benjamini, Y., and Y. Hochberg. 1995. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society B* 57: 289-300.
- Carr, D., Utzschneider, K., Hull, R., Kodama, K., Retzlaff, B., Brunzell, J., Shofer, J., Fish, B., Knopp, R., & Kahn, S. (2004). Intra-abdominal fat is a major determinant of the National Cholesterol Education Program Adult Treatment Panel III criteria for the metabolic syndrome. *Diabetes*, 53: 2087–2094.
- Center for Disease Prevention and Control. (2017, April 11). Defining Adult Overweight and Obesity. Overweight & Obesity. Retrived from <https://www.cdc.gov/obesity/adult/defining.html>.

- Chastin, S., De Craemer, M., De Cocker, K., Powell, L., Van Cauwenberg, J., Dall, P., Hamer, M., & Stamatakis, E. (2018). How does light-intensity physical activity associate with adult cardiometabolic health and mortality? Systematic review with meta-analysis of experimental and observational studies. *British Journal of Sports Medicine*, 0:1-8.
Doi:10.1136/bjsports-2017-097563.
- Chastin, S., Egerton, T., Leask, C., & Stamatakis, E. (2015). Meta-analysis of the relationship between breaks in sedentary behavior and cardiometabolic health. *Obesity (Silver Spring)*, 23(9). 1800-1810.
- Chodzko-Zajko, W., Proctor, D., Singh, M., Minson, C., Nigg, C., Salem, G., Skinner, J. (2009). Exercise and physical activity for older adults. *American College of Sports Medicine*, DOI: 10.1249/MSS.0b013e318a0c95c.
- Chipperfield, J., Newall, N., Chuchmach, L., Swift, A., & Haynes, T. (2008). Differential determinants of men's and women's everyday physical activity in later life. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, 63(4), S211-S218.
- Choi, L., Z, Liu, Z., Matthews, C., & Buchowski, M. (2011). Validation of accelerometer wear and nonwear time classification algorithm. *Medicine & Science in Sports & Exercise*, 43(2): 357-64.
- Colbert, L., Matthews, C., Havighurst, T., & Schoeller, D. (2011). Comparative validity of physical activity measures in older adults. *Medicine & Science in Sports & Exercise*, 43(5), 867-876.
- Crichton, G. & Alkerwi, A. (2015). Physical activity, sedentary behavior time and lipid levels in the Observation of Cardiovascular Risk Factors in Luxembourg study. *Lipids in health and disease*, 14: 87.

- Dacey, M., Baltzell, A., & Zaichkowsky, L. (2008). Older adults' intrinsic and extrinsic motivation toward physical activity. *American Journal of Health Behavior, 32*:570.
- Deci, E. & Ryan, R. (1985). Intrinsic motivation and self-determination in human behavior. New York: Plenum Press.
- Edwards, M. K. & Loprinzi, P. D. (2018). High amounts of sitting, low cardiorespiratory fitness, and low physical activity levels: 3 key ingredients in the recipe for influencing metabolic syndrome prevalence. *American Journal of Health Promotion, 32*, 587-594.
- Evanson, K., Buchner, D., & Morland, K. (2012). Objective measurement of physical activity and sedentary behavior among US adults aged 60 years or older. *Preventing Chronic Disease, 9* (26).
- Ferrannini, E., Haffner, S., Mitchell, B., & Stern, M. (1991). Hyperinsulinemia: the key feature of a cardiovascular and metabolic syndrome. *Diabetologia, 34*: 416-422.
- Figueiro, T., Arins, G., Silva dos Santos, C., Cembranel, F., Medeiros, P., d'Osri, E., & Rech, C. (2019). Association of objectively measured sedentary behavior and physical activity with cardiometabolic risk factors in older adults. *PLoS One*, Doi: 10.1371/journal.pone.0210861.
- Ford, E., Giles, W., & Dietz, W. (2002). Prevalence of the metabolic syndrome among US adults: findings from the Third National Health and Nutrition Examination Survey. *JAMA; 287*:356 –359.
- Freedson, P., Melanson, E., & Sirard, J. (1998). Calibration of the computer science and applications, Inc. accelerometer. *Medicine & Science in Sports & Exercise, 30*(5): 777-81.

- Gando, Y., Murakami, H., Kawakami, R. & Tanaka, N. (2014). Light-intensity physical activity is associated with insulin resistance in elderly Japanese women independent of moderate- to vigorous-intensity physical activity. *Human Kinetics Journal*, 11(2): 266-271.
- Goldbacher, E., & Matthews, K. (2007). Are psychological characteristics related to risk of the metabolic syndrome? A review of the literature. *Annals of Behavioral Medicine*, 34(2), 240-252.
- Grundy, S. (2008). Metabolic syndrome pandemic. *Arteriosclerosis, Thrombosis, and Vascular Biology*, 28: 629–636.
- Grundy, S., Cleeman, J., Daniels, S., Donato, K., Eckel, R., Gordon, D., Krauss, R., Savage, P., Smith, S., Spertus, J., & Costa, F. (2005). Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation*, 112:2735–2752.
- Gu, D., Reynolds, K., Wu, X., Whelton, P., & He, J. (2005). Prevalence of the metabolic syndrome and overweight among adults in China. *Lancet*, 365:1398–1405.
- Harvey, J. A., Chastin, S. F. M., & Skelton, D. A. (2013). Prevalence of sedentary behavior in older adults: a systematic review. *International Journal of Environmental Research and Public Health*, 10(12), 6645–6661.
- Hawkins, M., Gabriel, K., Conroy, M., Cooper, J., & Sutton-Tyrrell, K. (2013). Physical activity intensity and cardiovascular risk by ankle-brachial index. *Vascular Medicine*, 18:79–84.
- Healy, G., Dunstan D., Salmon, J., Cerin, E., Shaw, J., Zimmet, P., & Owen, N. (2007). Objectively measured light-intensity physical activity is independently associated with 2-h plasma glucose. *Diabetes Care*, 30:1384–9.

- Janssen, I., & Ross, R. (2012). Vigorous intensity physical activity is related to the metabolic syndrome independent of the physical activity dose. *International Journal of Epidemiology*, 41: 1132–1140.
- Jeon, C., Lokken, R., Hu, F., Van Dam, R. (2007), Physical activity of moderate intensity and risk of type 2 diabetes: a systematic review. *Diabetes Care*, 30:744–752.
- Kuk, J. & Arden, C. (2010). Age and sex differences in the clustering of metabolic syndrome factors: association with mortality risk. *Cardiovascular and Metabolic Risk*, 33(11): 2457-2461.
- Kulinski, J., Khera, A., Ayers, C., Das, S., De Lemos, J., Blair, S., & Berry, J. (2014). Association between cardiorespiratory fitness and accelerometer-derived physical activity and sedentary time in the general population. *Mayo Clinic Proceedings*, 89(8): 1063-71.
- Lakka, T., & Laaksonen, D. (2007). Physical activity in prevention and treatment of the metabolic syndrome. *Appl Physiol Nutr Metab*, 32:76–88.
- Lee, I., & Paffenbarger, R. (2000). Associations of light, moderate, and vigorous intensity physical activity with longevity. The Harvard Alumni Health Study. *American Journal of Epidemiology*, 151:293–299.
- Lemieux, I., Pascot, A., Couillard, C., Lamarche, B., Tchernof, A., Almeras, N., Bergeron, J., Gaudet, D., Temblay, G., Prud'homme, D., Nadeau, A., & Despres, J. (2000). Hypertriglyceridemic waist: a marker of the atherogenic metabolic triad (hyperinsulinemia; hyperapolipoprotein B; small, dense LDL) in men? *Circulation*, 102: 179–184.

- Lin, Y-C., Hsiao, T-J., & Chen, P-C. (2009). Persistent rotating shift work exposure accelerates development of metabolic syndrome among middle-aged female employees: A five-year follow-up. *Chronobiology International*, 26, 740-755.
- Loprinzi, P. (2015). Need for increased promotion of physical activity among adults at risk for Alzheimer's disease: A brief report. *Journal of Physical Activity and Health*, 12, 1601-1604.
- Manns, J., Dunstan, D., Owen, N., & Healy, G. (2012). Addressing the Nonexercise Part of the Activity Continuum: A More Realistic and Achievable Approach to Activity Programming for Adults With Mobility Disability?, *Physical Therapy*, 92(4): 614–625,
- Mozumdar A, & Liguori, G (2011). Persistent increase of prevalence of metabolic syndrome among U.S. adults: NHANES III to NHANES 1999–2006. *Diabetes Care*, 34: 216–219.
- National Center for Health Statistics, Division of Health Interview Statistics. (2012). *Crude and age-adjusted percentage of civilian, noninstitutionalized adults with diagnosed diabetes, United States, 1980–2010*. National Center for Chronic Disease Prevention and Health Promotion, Ed. Atlanta, GA, Centers for Disease Control and Prevention, Division of Diabetes Translation.
- National Cholesterol Education Program. Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) report. *Circulation*, 106: 3143-3421.
- O'Donoghue, G., Kennedy, A., Puggina, A., Aleksovska, K., Buck, C., Burns, C., ... Boccia, S. (2018). Socio-economic determinants of physical activity across the life course: A "DEterminants of DIet and Physical ACTivity" (DEDIPAC) umbrella literature review. *PLoS One*, 13(1), e0190737. doi:10.1371/journal.pone.0190737

- Park, S., Park, H., Togo, F., Watanabe, E., Tasunaga, A., Yoshiuchi, K., Shepard, & R., Aoyagi, Y. (2008). Year long physical activity and metabolic syndrome in older Japanese adults: cross-sectional data from the Nakanojo study. *The Journals of Gerontology: Series A*, 63(10), 1119-1123.
- Park, Y., Zhu, S., Palaniappan, L., Heshka, S., Carnethon, M., Heymsfield, S. (2003). The metabolic syndrome: prevalence and associated risk factor findings in the US population from the Third National Health and Nutrition Examination Survey, 1988–1994. *Archives of Internal Medicine*, 163: 427–436.
- Pradhan, A. (2014). Sex differences in the metabolic syndrome: implications for cardiovascular health in women. *Clinical Chemistry*, 60(1), 44-52.
- Reaven, G. (1988). Banting lecture: Role of insulin resistance in human disease. *Diabetes*, 37: 1595–1607.
- Rennie, K., McCarthy, N., Yazdgerdi, S., Marmot, M., & Brunner, E. (2003). Association of the metabolic syndrome with both vigorous and moderate physical activity. *International Journal of Epidemiology*, 32:600–606.
- Rezania, K., Solivan, B., Rezai, K., & Roos, R. (2011). Impaired glucose tolerance and metabolic syndrome in idiopathic polyneuropathy: The role of pain and depression, *Medical Hypotheses*, 76(4), 538-542.
- Ryan, A., Pratley, R., Goldberg, A. & Elahi, D. (1996). Resistive training increases insulin action in postmenopausal women. *Journal of Gerontologic Medicine*, 51A: M199-M205.
- Santos, A., Ebrahim, S., & Barros, H. (2008). Gender, socio-economic status and metabolic syndrome in middle-aged and old adults. *BMC Public Health*, 8:62.

- Sasaki, J., John, D., & Freedson, P. (2011). Validation and comparison of ActiGraph activity monitors. *Journal of Science and Medicine in Sport*, 15(5): 411-416.
- Sisson, S., Camhi, S., Church, T., Martin, C., Tudor-Locke, C., Bourchard, C., Earnest, C., Smith, S., Newton, R., Tankinen, T., & Katzmarzyk, P. (2009). Leisure time sedentary behavior, occupational/domestic physical activity, and metabolic syndrome in US men and women. *Metabolic Syndrome and Related Disorders*, 7(6).
- Stern, M., Williams, K., Gonzalez-Villalpando, C., Hunt, K., & Haffner, S. (2004) Does the metabolic syndrome improve identification of individuals at risk for type 2 diabetes and/or cardiovascular disease? *Diabetes Care*, 27(11): 2676-81.
- Sun, F., Norman, I., & While, A. (2013). Physical activity in older people: a systematic review. *BMC Public Health*, 13: 449.
- Teixeira, P., Carraça, E., Markland, D., Silva, M., & Ryan, R. (2012). Exercise, physical activity, and self-determination theory: A systematic review. *International Journal of Behavior Nutrition & Physical Activity*, 9:78.
- Toth, L., Park, S., Springer, C., Feyerabend, M., Steeves, J., & Bassett, D. (2018). Video-recorded validation of wearable step counters under free living conditions. *Medicine and Science in Sports and Exercise*, DOI: 10.1249/MSS.0000000000001569.
- Tsou, M. & Chang, B. (2013). Sex differences in metabolic syndrome of metropolitan elderly people in northern Taiwan. *Journal of Clinical Gerontology & Geriatrics*, 4:42-50.
- U.S. Census Bureau. (2018). Current Population Survey, Annual Social and Economic Supplement.
- Viscogliosi, G., Andreozzi, P., Chiriac, I., Cipriani, E., Servello, A., Marigliano, B., Ettorre, E., & Marigliano, V. (2013). Depressive symptoms in older people with metabolic

- syndrome: is there a relationship with inflammation? *International Journal of Geriatric Psychiatry*, 28: 242-247.
- Visser, D., Hens, W., Teymans, J., Baeyens, J., Poortmans, J., & Van Gaal, L. (2013). The effect of exercise on visceral adipose tissue in overweight adults: a systematic review and meta analysis. *PLoS One*, 8:e56415.
- Watts, A., Walters, R., Hoffman, L., Templin, J. (2016). Intra-individual variability of physical activity in older adults with and without Mild Alzheimer's disease. *PLoS One*, 11:4, doi:10.1371/journal.pone.0153898.
- Weiss, R., Dziura, J., Burgert, T. S., Tamborlane, W. V., Taksali, S. E., Yockel, C. W., Allen, K., Lopes, M., Savoye, M., Morrison, J., Sherwin, R. S., & Caprio, S. (2004). Obesity and the metabolic syndrome in children and adolescents. *The New England Journal of Medicine*, 350, 2362-2374.
- Wu, B., & Porell, F. (2000). Job characteristics and leisure physical activity. *Journal of Aging and Health*, 12: 538-559.
- Yang, X., Telama, R., Hirvensalo, M., Mattsson, N., Viikari, J., & Raitakari, O. (2008). The longitudinal effects of physical activity history on metabolic syndrome. *Med Sci Sports Exerc*, 40:1424–1431.
- Young-Shin, L. (2005). Gender differences in physical activity and walking among older adults. *Journal of Women & Aging*, 17(1-2): 55-70.
- Yue, A., Woo, J., Ip, K., Sum, C., Kwok, T., & Hui, S. (2007). Effect of age and gender on energy expenditure in common activities of daily living in a Chinese population. *Disability and Rehabilitation*, 29(2): 91-96.

Appendix

Table 1

Demographics

Variable	Frequency (<i>n</i> =107)	%
Gender		
Male	35	32.7
Female	72	67.3
Ethnicity		
Non-Hispanic	106	99.1
Hispanic	1	0.9
Race		
White	99	92.5
Black or African American	6	5.6
Asian	1	0.9
APOE**		
e3/e2	8	7.7
e3/e3	69	66.3
e3/e4	25	24.0
e4/e4	2	1.4

**APOE *n* = 104

Table 2

Participant Characteristics

Variable	Male (<i>n</i> = 35)		Female (<i>n</i> = 72)		<i>t</i>	<i>p</i>
	Mean	<i>SD</i>	Mean	<i>SD</i>		
Age	76.31	6.29	74.03	6.19	-1.77	.080
Education	17.23	3.05	15.96	2.61	-2.12	.039*
% Sedentary	27.98	7.44	24.27	10.03	-2.15	.034*
% Light Physical Activity	48.76	5.72	46.86	7.01	-1.49	.138
% Moderate Physical Activity	22.86	7.40	28.81	9.73	-3.51	<.001*

Table 3

Metabolic Syndrome Risk Factors by Sex

Variable	Male (<i>n</i> = 35)		Female (<i>n</i> = 72)		<i>X</i> ²	<i>p</i>
	Frequency	%	Frequency	%		
Waist Circumference	18	51.4	35	48.6	0.07	.784
BMI**	10	39.4	16	22.2	0.54	.462
Diabetes	4	11.4	13	18.1	0.77	.379
Diabetes Medication	4	11.4	13	18.1	0.77	.370
Hypertension	13	37.1	40	55.6	3.20	.074
Hypertension Medication	20	57.1	46	63.9	0.45	.500
Hypercholesteremia	24	68.6	39	54.2	2.42	.156
Hypertriglyceridemia	26	74.3	37	51.4	5.09	.023*
Meets MetS Criteria	13	37.1	25	34.7	0.06	.806

**BMI *n* = 106, Male *n* = 34, female *n* = 72

Table 4

Logistic Regression Models for Metabolic Syndrome Risk Factors (*n* = 107)

Variables	Model 1 BMI		Model 2 Waist Circumference		Model 3 Diabetes		Model 4 Hypertension		Model 5 Hypercholesterolemia		Model 6 Hypertriglyceridemia	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
%LPA	1.06	0.97, 1.17	1.08	0.99, 1.16	0.95	0.76, 1.19	0.98	0.89, 1.08	1.05	0.98, 1.13	0.97	0.90, 1.04
Age	0.99	0.91, 1.08	0.98	0.91, 1.05	0.80	0.63, 1.02	1.03	0.94, 1.13	0.99	0.93, 1.06	0.96	0.89, 1.03
Education	0.72*	0.56, 0.93	0.90	0.77, 1.06	1.87	0.80, 4.38	0.75*	0.59, 0.95	0.86	0.73, 1.01	0.91	0.77, 1.07
Sex	0.01	0.00, 926.02	3.00	<0.001, 5438.14	<.001	<0.001, 4752301.33	<.001	<.001, 209.54	411.34	0.22, 761214.83	30.37	0.01, 73842.47
%LPA*Sex	1.11	0.88, 1.39	0.98	0.84, 1.15	1.78	0.76, 4.18	1.10	0.88, 1.40	0.90	0.77, 1.05	0.96	0.82, 1.12
Hypertension Medication	4.75*	1.19, 18.85	2.58*	1.02, 6.46	1.59	0.10, 25.35	70.54*	13.71, 362.76	1.57	0.65, 3.82	2.16	0.85, 5.48

LPA = light physical activity