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An Examination of Light Intensity Physical Activity and Health in Older Adults

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AN EXAMINATION OF LIGHT INTENSITY PHYSICAL ACTIVITY AND HEALTH IN OLDER ADULTS

by

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ABSTRACT

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Research has begun to quickly emerge on the potential benefit of light intensity physical activity (LPA) to the health of adults. Little is known about LPA, and much of the current LPA research stems from sedentary behavior research. The purpose of this dissertation was to more fully understand, describe, and characterize potential health benefits of LPA by determining the prevalence, patterns, and health benefits of light intensity physical activity in older adults. Three individual studies were completed to address each portion of this purpose. **Study 1: Light Intensity Physical Activity and Health in Adults: A Systematic Review.** The purpose of this study was to critically examine the current literature pertaining to LPA and whether research supported a benefit or lack of benefit to adults. Upon search, five health categories emerged and were examined: 1) all cause mortality, 2) metabolic health, 3) cardiovascular health, 4) cancer risk, and 5) functional health. Overall findings suggested there may be benefit to incorporating LPA within the day in order to decrease risk of all-cause mortality, decrease insulin resistance, c-reactive protein, glucose, insulin, metabolic syndrome, physical function, and increase cognition. The results from this review suggested adults who were inactive,

had been diagnosed with a chronic disease, or those who were older, showed a greater benefit to engaging in LPA than those who were healthy and physically active. **Study 2: Contextual Analysis of Physical Activity.** The second study was an observational study to describe the patterns and context of LPA in older adults by measuring their physical activity over seven days and the context of their LPA was recorded on one day for a simultaneous measurement. Our results suggested older adults engaged in over 250 min per day of LPA, in mostly short, frequent bouts (~2.5 min each bout). LPA was performed for a consistent 15-25 min each hour from 7am until 7pm. When activity domain was examined, over half of the activity occurred during participants' leisure time. Popular specific activities included leisure-time activities such as multi-tasking while watching television or on the computer, shopping, and household activities such as cooking and cleaning. Contextual measurement revealed the LPA was more commonly performed inside when the participant was by themselves, as opposed to with a group. Understanding what LPA activities are already prevalent and specific to older adults, the social support necessary to elicit the behavior, and the location these activities most commonly occur to help identify potential barriers to the activity prescription (weather, transportation, resources, etc.). **Study 3: Dose response to LPA and glucose dynamics in older adults.** The purpose of this study was to determine whether there was a dose-response relationship between the total amount of time spent in LPA and post-prandial glucose response in older adults. Results from these trials showed there was a significant decrease in glucose area under the curve 3-hours post-meal when 40% of the measured time was spent in LPA. This effect was

further compounded when time spent in LPA was increased to 60% of the measurement period. This study was one of the first with an explicit focus on LPA and provides evidence there is a metabolic health benefit to engaging in LPA, that can further increase in benefit with increasing time spent in lower intensity activities. **Overall Conclusion.** Together these studies provide evidence that LPA may be a feasible physical activity selection for older adults and these active behaviors, even at low intensities, may be health enhancing. Study 1 provides a solid foundation to understand what we already know by what has been published in the literature, Study 3 answered the question of whether or not LPA would provide a sufficient stimulus to alter glucose uptake and further still whether that response would be dose-dependent, and Study 2 results will assist health and fitness professionals and researchers in designing and developing appropriate LPA prescriptions. As our results directed, activity data from objectively measured LPA showed LPA activities, therefore prescription development, are not synonymous with moderate and vigorous activities and therefore should be considered individually. These outcomes provide an important, positive impact on population health by providing evidence for older adults to be physically active through a potentially more attainable approach in order to gain health benefits.

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CHAPTER 1: INTRODUCTION

Background

Adults with chronic disease in the United States have cost the economy over one trillion dollars per year in medical costs over the last 10 years (23). Associated with high prevalence of chronic disease are low levels of physical activity, of all intensities, and high levels of sedentary behaviors, resulting in a largely inactive and sedentary adult population. Older adults are of particular interest. Studies have demonstrated a significant decrease in time spent in activity of all intensities with age, with the largest decrease seen in light intensity physical activity; a 35% decrease from age 35 years to 85 years of age (144). When examining temporal patterns of daily activity, studies have shown that the majority of daily active time is spent performing ubiquitous activities that are of a light intensity level, therefore, researchers have begun to elucidate the importance of light intensity activities to our total daily energy expenditure and provide evidence for the beneficial health effects of these light intensity movements (27, 37, 94).

Incorporating moderate or vigorous activities (MVPA) into daily life can be cumbersome and for inactive and sedentary older adults may pose not only a behavioral challenge but a physiological one as well (65). Only 25.3% of older adults report meeting the current MVPA recommendations of accumulating 150 minutes per week of moderate intensity activity, 75 minutes of vigorous intensity activity, or some combination of the two (38). Due to this low adherence, development of light intensity physical activity recommendations could increase physical activity

participation among this population. Therefore, it is proposed light intensity physical activity could provide a feasible and attainable activity option for the older adult population to increase physical activity levels and therefore improve health.

Recent research has shown that engaging in light intensity physical activity is associated with positive health benefits. In particular, light intensity physical activity (LPA) is associated with higher individual-rated health and more favorable cardiometabolic biomarkers, including greater glucose regulation in older adults (21, 54). Previous research by Healy and colleagues has shown decreased glucose tolerance test peak glucose excursion in adults who accumulate a greater amount of LPA (54). Additionally, it has been shown that breaking up sedentary times with short light intensity bouts (2 minutes) is as beneficial at enhancing glucose control as moderate intensity activity breaks (35). Thus, there is an urgent and critical public health need to further understand light intensity physical activity. Although little research has been done, the initial groundwork has been laid informing researchers there appears to be an independent benefit to engaging in light intensity physical activity (94).

Since light intensity physical activity already accounts for a large portion of an older adults ubiquitous activities, if beneficial, increasing light intensity physical activity may be more feasible for older adults, adults with chronic diseases, or those individuals' beginning at low baseline activity levels (3). However, many gaps still remain about the current prevalence of light intensity physical activity in older adults, the most common types of light intensity activities performed by this

population, and the potential dose-response benefit to increasing light intensity activity above baseline levels.

Statement of Purpose

The purpose of this dissertation was to determine the prevalence, patterns, and health benefits of light intensity physical activity in older adults.

Specific Aims & Hypotheses

Study 1:

Light Intensity Physical Activity: A Review

Specific Aim: Synthesize the current observational, longitudinal, and interventional evidence and present a summary of the best evidence available for light intensity physical activity as a mechanism for health enhancement.

Study 2:

Contextual Analysis of Physical Activities in Older Adults

Specific Aim #1: Define the pattern of light intensity physical activity in older adults.

Hypothesis #1: Older adults will spend a larger proportion of their time in light intensity physical activity during the morning hours when compared to the afternoon hours, since previous research examining moderate and vigorous activities show these active behaviors are greater during the first half of the day (101).

Hypothesis #2: Light intensity bouts will more often be performed in short, sporadic (<10 min) bouts versus longer, sustained bouts (>10 min) of activity. This hypothesis stems from examining what activities are considered LPA within the Compendium of Physical Activities; most of them being short in duration, ubiquitous activities (3).

Specific Aim #2: Identify the activities and domains of activities specific to light intensity physical activity.

Hypothesis #1: Household-related activities, such as cooking or cleaning will be the most prevalent light intensity physical activity performed by older adults, as has been reported previously by subjective measurement (136).

Hypothesis #2: The majority of light intensity physical activity will be performed inside the older adult's residence, in line with typical locations of the highly reported activities (136).

Study 3:

Dose-Response of Light Intensity Physical Activity and Glucose Dynamics in Older Adults

Specific Aim #1: Determine the effect light intensity physical activity on glucose response in older adults in a controlled environment.

Hypothesis #1: Glucose area under the curve will be lower during the three-hour monitoring period following accumulation of light intensity physical activity, when compared to the seated condition.

Specific Aim #2: Determine the dose-response effect of proportion of time spent in light intensity physical activity on glucose response in older adults in a controlled environment.

Hypothesis #1: Glucose area under the curve will progressively decrease as time spent in light intensity physical activity increases.

Assumptions of the Studies

These studies assume the following:

- Participants will answer questions honestly during participant screening and data collection.
- Participants' follow all the pre-participation guidelines laid out by the researcher.
- Participants will answer activity questionnaires free of researcher desirability bias.
- Participants will wear their accelerometer as directed by the researcher, including remembering to put them on upon waking and recording wear times on their activity logs provided.
- Participants will follow directions on maintaining their normal activity regimens and not become biased by the presence of the monitor.

Limitations of the Studies

A limitation to these studies is related to the specific populations being studied within each study, decreasing ability to generalize to other populations.

However, these findings could provide rationale to further elucidate the effects of light intensity physical activity among differing populations and provide information on the importance of light intensity physical activity to improve glucose control. These results will be used to inform future LPA interventions. Limitations to accelerometer data reduction will exist regardless of the reduction technique chosen, as there are limitations to all currently developed analyses. The controlled laboratory setting with which it will be conducted limits study three. For example, participants will be walking on a treadmill as opposed to a self-selected free-living, over-ground environment. Additionally, we will simulate proportion of a waking day spent in light intensity physical activity by extrapolating a three-hour monitoring period into a full day. Due to the measurement of energy expenditure, an all-day measurement period is not feasible and the current study design additionally allows for a more tightly controlled experiment.

Significance of the Studies

These studies provide practical and scientific significance by filling knowledge gaps in determining the current state of light intensity physical activity in an older adult population, commonly performed light intensity activities, and the health benefits associated with differing quantities of light intensity activity. The ultimate goals of these studies are to provide evidence to prescribe light intensity physical activity as a means of increasing health and decreasing the chronic disease burden on the older adult population. Scientifically, these studies can move the field of physical activity and public health forward by elucidating the effect of a lower

intensity physical activity, which may provide a more easily attainable activity option to a variety of populations and have an overall effect of increasing health and decreasing chronic disease. Additionally, understanding when, where and how individuals are engaging in these behaviors will help in developing more sustainable and behavior-changing interventions. Practically, the light intensity message may translate as a more palatable message to older adults and similar populations and aid clinicians and exercise specialists in their exercise and activity prescriptions as a cost-effective alternative to preventing and decreasing disease.

The following dissertation is set up as a three-study sequence, which fills the aforementioned knowledge gaps by critically examining what is currently known about light intensity physical activity, providing a holistic understanding of light intensity physical activity participation in older adults by incorporating context of activity into LPA measurement, and determining dose-response to light intensity physical activity and glucose dynamics. Together these results provide a solid foundation for the future development of light intensity physical activity promotion and prescription in the older adult population.

CHAPTER 2: REVIEW OF LITERATURE

Introduction

Since the 1950's and the seminal work of Jeremy Morris, the benefits of physical activity have been the focus of many researchers and practitioners around the world (112). Much of the early work focused on understanding the benefits of physical activity of higher intensities, namely moderate-to-vigorous activity (MVPA). With the growth of knowledge about the benefits of physical activity great interest grew in the effect of overall physical activity accumulated (any movement that results in energy expenditure), as opposed to the single dimension of exercise, as a planned and structured activity for the purpose of increasing fitness. Examination of daily patterns of activity intensities revealed adults spend very little of their waking day in MVPA; the majority of people's waking day is spent performing sedentary behaviors or light intensity physical activities (115).

Throughout the evolution of the physical activity guidelines, more and more has been revealed about the relationship between more purposeful, active living (MVPA) or sedentary behaviors and health outcomes (16). While much attention has been paid to MVPA and sedentary behaviors, little research has explored the benefits of light intensity physical activity. However, it begs the question that if one buys into the notion that sedentary behavior is bad, would that indicate therefore, that LPA is good?

Light intensity physical activity is defined as metabolic equivalent (MET) values greater than one and one-half and less than three (3, 123), which intermediate the intensities in between moderate intensity activity and sedentary activities. In general, LPA are our everyday activities such as household activities of daily living, slow walking or walking as the result of completing other task such as cleaning, or low-level leisure-time activities. Older adults' prevalence data has shown 30% of their day is spent in active behaviors with LPA making up 79% of that active time. To date, little research has examined the role of light intensity physical activity as a critical portion of our daily-accumulated movement. Little attention has been given to the current prevalence and context of LPA-related behaviors and in addition, the health benefits associated with an increase or decline in LPA over the life course.

This review seeks to fill this gap by reviewing the current state of knowledge on LPA through a discussion of: 1) the currently held definitions of light intensity, 2) examples of the types of activities that would fall within this spectrum, 3) the measurement of LPA, 4) reported prevalence of LPA, 5) the relationship of LPA to health, and 6) experimental results of LPA on health.

Defining Physical Activity Intensity

In order to understand LPA and its relation with health, it is first important to review how physical activity is defined and measured. Physical activity is generally described by four attributes: the frequency with which the activity is performed, the intensity with which the activity is performed, the type or mode of

activity performed, and/or the duration of the activity (63). Frequency, type, and duration attributes are all easily and objectively measured by counting the number of times you engaged in an activity over a specified time period (frequency), measuring the amount of time spent in a certain activity over a specified time period (duration), or by noting the mode of the activity performed (mode or type). However, quantifying intensity poses a more difficult challenge due to the multiple methods of measurement that assess various physiological, mechanical, and/or psychological indicators of intensity, and the numerous ways intensity can be expressed.

Intensity is defined as the overload placed on physiological systems that elicits a training response (116); this load is most ideally measured through the metabolic (oxygen consumption) and cardiovascular (heart rate) systems. Intensity is often broken into distinct categories; example categories include light, moderate, and hard, with each category increasing the intensity with which you are working. Clearly defining what differentiates each intensity category becomes quite a bit more complex.

There are two commonly accepted approaches to present intensity data: in relative or absolute terms. Relative intensity is expressed in relation to the individuals' maximal physiological capacity of work, such as a percentage of their maximal heart rate or VO_2. In a sample of individuals that are similar in age, sex, and training state these absolute and relative values will remain rather similar to one another however, when this is not the case the relative method of expressing intensity is more tailored to the individual's current health and fitness level because

maximal capacity can be affected by factors such as sex, age, and training state, making it an important and accurate indicator of how hard someone is working (51). Exercise intensity can also be described in absolute terms, based on the individual's physiologic response (Liters of oxygen consumed per minute, METs) or based on the activity performed (walk at 3 mph and 0% grade on a motorized treadmill, METs). Absolute intensity provides an expression provides a set rate of energy expended for a given work rate or activity (51). This set rate approach allows for a less individualized however more translational application of intensity. These approaches to describe intensity will be detailed in the following sections.

Relative Intensity

Relative intensity is expressed as either a percentage of an individual's maximal heart rate, heart rate reserve, or maximal oxygen consumption (VO_{2max}). Relative intensity terminology was used in the first physical activity guidelines documented in 1965 by the President's Council of Physical Fitness and intensity recommendations were presented in relative terminology until 1995 when the Center for Disease Control and Prevention and American College of Sports Medicine published their updated guidelines recommending engaging in moderate activity (123). Thereafter, recommendations were also provided in absolute terms in an attempt to provide a more easily understandable and measureable public health message.

Being able to more accurately quantify an individuals actual intensity during an activity is why utilizing relative intensity can be incredibly beneficial. It provides

an individualized prescription and is the most common way activity prescriptions are given (107). There are limitations to using relative intensity definitions. Relative intensity quantification requires knowledge and measurement (or estimation) of maximal heart rate or VO_{2max}. Measurement of maximal HR and/or VO_2 is not feasible or easily accessible for all populations. Rhe technical measurement of these variables require either the utilization of expensive equipment and/or a trained technician. Estimation of maximal HR and/or VO2 is also available through field tests or prediction equations. However, the validity and reliability of these techniques are not high across all populations (132).

When expressing intensity relative to an individual's maximal capacity, there is no standardization. Depending on the source, the relative cut-offs for each intensity category differ. According to the 1996 Surgeon General's Report on Physical Activity and Health, light intensity was classified as 25-44% VO_{2max} or heart rate reserve, 30-49% heart rate max, or a 9-10 on Borg's rating of perceived exertion scale (123). Then in 2008, United States Health and Human Services put out the current physical activity guidelines for health benefits(137) and no relative intensity provided for LPA was given. However, one can surmise that it is less than the moderate activity range, and therefore less than 40% VO_{2max}.

In a call to researchers to standardize relative intensity values, Norton and colleagues (114) reported relative intensity values for each intensity category, which are reported below (Table 1).

Table 1. Categories of Exercise Intensity (114)

Intensity	Heart Rate Max (%)	Heart Rate Reserve (%)	VO2max (%)
Sedentary	<40	<20	<20
Light	40-55	20-40	20-40
Moderate	55-70	40-60	40-60
Vigorous	70-90	60-85	60-85
High	>90	>85	>85

Together, these show there is currently no standardized definition for LPA. However, the above definitions of LPA differ by only about ±5%, with the upper bound range for LPA ranging from 40-44% of VO_{2max}.

Absolute Intensity

Alternatively, intensity can be expressed in terms of absolute work done (e.g. 300 Watts on a cycle ergometer), or absolute physiologic demand (e.g. L/min, MET). These values are consistent across individuals, meaning that 300 Watts is the same workload regardless of the person. Further, absolute expression of intensity is not influenced by factors such as age or training status. Absolute intensity is most commonly expressed as a MET or metabolic equivalent. The most commonly accepted MET definition today is 1 MET is equivalent to 3.5 ml/kg/min (2). In 1960, Bruno Balke was the first to use the term MET in exercise physiology to describe the work to rest ratio (8). The MET was introduced to provide an "easy" all encompassing measurement of intensity level. This ratio of work to rest, provides a

quickly estimated and understood definition of intensity; each single increase in MET value indicating a single increase in work above resting values. Benefits of expressing intensity in an absolute manner include an intensity estimate that can be obtained from the Compendium of physical activities based on activity (3) performed and monitored with minimal invasive physiological information, and absolute intensity provides easy comparisons across populations.

However, there are some limitations to using absolute intensities to describe physical activity. Older adults and adults with low fitness levels are likely working at a much higher relative intensity than a trained individual while performing the same activity at the same absolute intensity level (124). Additionally, many have found that the 3.5ml/kg/min "resting" level is generally higher than most individuals' measured resting metabolic rates, therefore, misclassifying the intensity at which these individuals are working (76, 77).

Similar to relative intensities, there is no standardized cut-offs when expressing intensity in absolute terms. In the 2008 guidelines, LPA was defined as between 1.1 and 2.9 METs, moderate falls within 3.0 and 5.9 METs, and vigorous activity constituting of any MET values at and above 6 (137). In contrast, the Sedentary Behavior Research Network published a call to researchers to standardize the definition of sedentary behavior to any absolute energy expenditure value equal to or below 1.5 METs (133). Likewise, Norton et al. attempted to standardize the remaining absolute intensity terminology (114). In line with the sedentary behavior research network definition, researchers defined sedentary behavior as any activity <1.6 METs, LPA as 1.6 to 2.9 METs, moderate activity as 3 to

5.9 METs, and vigorous activity 6 to 9 METs. To date, these are the most commonly used MET-defined intensity categories.

Again, as was seen in the relative intensity demarcations, there is no standardized definition of absolute LPA intensity when expressed in absolute terms. Although the majority of the literature utilizes the 1.6-2.9 MET cut-offs for LPA in adults, age and disease-state can all play important roles in researchers chosen intensity cut-offs (124).

Combining Relative & Absolute Intensity

To bring a standardized terminology and as an attempt to circumvent the limitations of METs as a function of an individual's relative capacity, the 1996 Surgeons General's Report on Physical Activity and Health, absolute intensity criteria (Table 2) are given in METs and are additionally broken up by age groups to take into account the variation in fitness levels over the lifespan (123).

Table 2. Classification of Absolute Intensity (METs) in Healthy Adults by Age (123)

Intensity	Young (20-39y)	Middle-aged (40-64y)	Old (65-79y)	Very Old (80y +)
Light	3.0-4.7	2.5-4.4	2.0-3.5	1.26-2.2
Moderate	4.8-7.1	4.5-5.9	3.6-4.7	2.3-2.95
Hard	7.2-10.1	6.0-8.4	4.8-6.7	3.0-4.25

In 2001, Howley proposed a scale of MET values dependent on the individual's maximal capacity to address the same issue (62). Table 3 provides MET estimates based on VO_{2max} levels, therefore, those who have a higher VO_{2max} will be working at a higher MET value at a lower percentage of their VO_{2max}.

Table 3. Classification of Physical Activity Intensity by Maximal Fitness Level (62)

VO2max	12 METs		10 METs		8 METs		5 METs	
	METs	VO_{2max} (%)	METs	VO_{2max} (%)	METs	VO_{2max} (%)	METs	VO_{2max} (%)
Light	3.2-5.3	27-44	2.8-4.5	28-45	2.4-3.7	30-47	1.8-2.5	26-51
Moderate	5.4-7.5	45-62	4.6-6.3	46-63	3.8-5.1	48-64	2.6-3.3	52-67
Hard	7.6-10.2	63-85	6.4-8.6	64-86	5.2-6.9	65-86	3.4-4.3	68-87

As highlighted above, there are a number of ways to measure and express intensity, each with their own strengths and limitations. Determining intensity expression is highly dependent on the outcome of interest and the testing or exercising environment. However, what is lacking from the current literature is a clear and consistent definition of light intensity. Since LPA has become the "between" intensity of the greater studied moderate intensity and sedentary behavior, standardization of these intensity cut-offs could additionally aid in standardization of the LPA definition.

Measurement of Light Intensity Physical Activity

Whether light intensity is expressed in relative or absolute terms, both values must be measured for the most precise understanding of an individual's intensity level. More rigorous measurements involve tracking physiological information, such as heart rate or maximal oxygen consumption, however when these are not feasible other measurement estimation techniques have been developed that provide the ability to track individuals in a free-living setting or over a long period of time.

Physiological Measurement of Intensity

There are two main physiological variables and one psychological variable that are measured in order to provide an estimate of an individuals' physical activity intensity: heart rate, oxygen consumption, and a rating of perceived exertion, respectively.

Oxygen Consumption. Oxygen consumption or VO_2 is a measurement of the aerobic metabolic processes (the amount of oxygen used by muscles) used to produce ATP. VO_2 is most commonly measured through estimation of oxygen consumption by indirect calorimetry (104). In terms of intensity measurement and classification, percent of VO_2 max is considered the gold standard measurement of intensity level when maximal VO_2 is known (104). A VO_{2max} is most commonly measured by a graded exercise test, or a test in which the work output of an exercise mode is increased until volitional fatigue (108). VO_{2max} and submaximal VO_2 values can also be estimated using field tests or derived energy cost equations.

Heart Rate. Berggren and Christensen found that heart rate increases linearly due to an increased need of oxygen at the muscle in response to increasing level of physical activity (14). If an individual's maximal heart rate is known then a percentage of the maximal heart rate can be used as their relative intensity. Monitoring heart rate is a good alternative for individuals to assess their own physical activity intensity due to it's low cost and low technical skill required, when compared to other lab-based procedures such as oxygen consumption. However, limitations to this method do exist. Until sympathetic stimulation is accelerated to elicit the increase in the heart rate response above approximately 120 beats per minute, heart rate can be falsely elevated in response to other cardiac accelerators such as anxiety or stress which is especially problematic when measuring light intensity activities (64).

Rating of Perceived Exertion. Borg's rating of perceived exertion scale was developed as a subjective rating of perceived effort and fatigue of an activity. Individuals rate how hard they feel the exercise or activity is on a scale of 6 to 20.(17). Similar to heart rate and VO_2 responses, the perceived effort of an activity should increase linearly with increasing effort or intensity.

The rating of perceived exertion is considered a psychological construct, however, in field-based research or research lacking more rigorous means of measurement, this scale is used as a proxy for intensity. Therefore, knowledge of the rating of perceived exertion scale to accurately portray light intensities is important for future research translation.

Following Borg's original contribution of the perceived 6 through 20 scale, he proposed a categorical 1 through 10 scale based on the same ratio properties used in the original 15 point scale, with the intent of making it a more understandable scale (18). While the rating of perceived exertion was rescaled in order to provide a more simple and understandable anchoring for individuals, Borg wrote the original 6 through 20 scale was overall the better measure of subjective perception when it was applicable to use.

To date, there have not been any studies to show specifically the utility of any of these methods to assess LPA; rather, light intensity activity has become the default intensity between highly researched inactivity and moderate intensity activity. Overall VO_{2max} provides the gold standard measurement of intensity while measures of maximal heart rate, and RPE to specifically measure LPA is not known. Since intensity is so contingent on being relative to the person, which would be dependent on age and training status, filling this knowledge gap would provide more information and estimation accuracies to the measurement of LPA.

Free Living Estimation of Intensity

Of additional interest in assessing physical activity outside of the laboratory, under free-living conditions, it became necessary for other field-based methods to assess physical activity that are portable and able to assess activity over long periods of time. These measurements fill many research feasibility needs, for example allowing monitoring of activity over longer time periods (a week or multiple weeks), measuring intensity for large populations of individuals, and

decreasing the participant burden of physiological measurements (80, 85). The following section will provide an overview of both the subjective (questionnaires) and objective (activity monitors) estimation techniques to classify intensity.

Self-Report. Self-report measurement tools are generally survey type measurements where the participant is being asked to recall or report their activity or perceived intensity level on a questionnaire, log, or diary (80). These measurement tools have shown moderate comparative validity with physical activity monitors for exercise or MVPA since these activities are usually performed for a purpose and are planned (85, 127). However, self-report measurements are not accurate at measuring LPA (2). This could stem from the difficulty of recalling these activities since a large percentage are everyday activities of daily living, or for some of the activities, such as household walking, the lack of purposeful decisions that go into engaging in light intensity activities. Most self-report measurement tools were not designed to capture light intensity activity, therefore, few tools are available to assess LPA.

To address the lack of LPA survey measurement tools, Barwais et al. have developed a self-report measure called the Sedentary Behavior and Light Intensity Physical Activity Log (SLIPA) that encompasses a rather comprehensive list of sedentary and light intensity activities (10). The survey was developed by consulting the compendium of physical activity for light and sedentary activities, followed by interviewing individuals on their recall and time spent in LPA or sedentary behavior. The survey's validity was assessed on an independent sample of 22 young adults. Results showed the SLIPA survey had a strong correlation with

Actigraph GT3X inclinometer measured sitting and standing time (r=0.80). When light intensity is specifically examined (ActiGraph time spent standing), mean difference (SLIPA-GT3X) showed a 1.8-hour difference between the accelerometer and survey measure for one 24-hour day, with the survey greatly underestimating time spent in LPA. These data are based on the assumption the inclinometer function within the Actigraph worn on the waist is a valid indicator of standing and sitting time. Additionally, it should be noted the authors were more interested in posture allocation with the dissemination of this survey and not necessarily intensity, therefore, the outcome variables are derived from standing, sitting, and lying time. Because of the lack of available measures and the limitations to the light intensity survey available, light intensity measurement is ripe for survey development to more accurately capture light intensities.

Objective Measurement. Since self-report measurement tools do not accurately capture light intensity physical activities, finding other ways to measure intensity with little burden on the participant is important. One option, estimating LPA with accelerometer-based physical activity monitors, which holds promise for light intensity estimation. These activity monitors contain an accelerometer, which translates bodily movements into substantive quantitative data (25). Accelerometers were first applied to the measurement of activity intensity in the early 1980's with the finding that with an increase in energy expended (or increased activity intensity) the body moves quicker, therefore, registering higher accelerations providing a quantification of body movement (111).

Most commonly, activity monitors are worn on the waist (142). This monitor placement has proven to be an accurate indicator of ambulatory activity due to the consistent and cyclical vertical accelerations produced during walking. Further, waist worn activity monitors have been shown to accurately measure slow walking (41). Therefore, waist worn monitors are a promising method to assess LPA since the majority of walking performed daily is ubiquitous and falls within the light intensity range.

To date, the most commonly used and traditional analysis of accelerometer-based activity monitor data was through linear regression-derived cut-points to classify movement as sedentary or inactivity, light-intensity, moderate-intensity, or vigorous-intensity. These cut-points correspond to the absolute MET value cut-offs for light, moderate, and vigorous activities. Calibration of the cut-points is performed by measuring oxygen consumption during a number of different activities, usually in a laboratory setting with simulated activities. The first few published cut-points were developed on ambulatory activities alone with lifestyle activities being added to calibration protocols a few years later (43, 58, 130, 134). As is illustrated in Table 4, there are a number of different published cut-points. Each set of cut-points has their own strengths and limitations, due to the protocol and/or methods used for development. Previous cross-validation of the waist-worn cut-points have shown little agreement between LPA cut-points and measured energy expenditure. The cut-points derived from Swartz et al. (130) showed the closest agreement with no significant differences seen between measured time spent in LPA, while other cut-points overestimated LPA by as much as 29%

(Hendelman et al. (58)). Authors' reasoned the Swartz estimation faired well during light activities due to the calibration activities consisting largely of lifestyle activities (126, 130).

Table 4. Most Common Vertical Axis Waist Cutpoints

Cutpoint	Calibration Protocol	Light Intensity Cutpoint
Freedson et al. (43)	Ambulatory	<1952 counts/min
Hendelman et al. (58)	Lifestyle activities	<2192 counts/min
Nichols et al. (113)	Ambulatory	<1982 counts/min
Swartz et al. (130)	Lifestyle activities	<574 counts/min
Troiano et al. (134)	Ambulatory	<2020 counts/min

An overarching limitation of these cut-points are they are derived from absolute intensity MET values, not taking into account physiological variables which are different from the calibration population (12). The above cited cut-points were developed on an adult population, therefore their generalization to older adults is limited (128). A few older adult specific cut-points have been developed and the most commonly used older adult cut-points are described. Copeland et al. used lab-based treadmill walking to develop cut-points in older adults (28). Light intensity cut-points on the vertical axis were <1041 cpm. In 2013, Hall et al. developed cut-points on slow walking (1.5-3.5 mph) in 60-90 year olds. Light intensity cut-point showed a lower vertical axis cut-point than previously derived from other older adult research (LPA<809 cpm) (48). Most recently, MVPA and sedentary cut-points

were developed using the vector magnitude in older adults (1). Sedentary cut-points for estimating time spent sitting, lying, and standing are <1 cpm at 1-s epoch, <70 cpm at 15-s epochs, and <200 cpm at 1-min epochs (1). MVPA cut-points were age and gender specific, however, cross-validation showed they were not accurately predicting energy expenditure (120). Similar limitations exist with these cut-points as with the adult cut-points, including calibration on a single activity (walking) and not taking into account individual differences in relative intensities that are apparent in older age (12, 110, 127).

A promising avenue for exploration to improve the accuracy of estimating LPA may be the measurement of acceleration at the wrist. Accelerometers worn on the wrist allow the capture of upper body movement in the absence of concurrent lower body movement. An example where this would be important is with standing. According to the compendium of physical activity, standing still is below the light intensity MET level (1.3 METs) while standing with upper body movement is considered a light intensity activity (2.0 METs) (3). This activity therefore would classified as sedentary by the waist-worn accelerometer, while the wrist-worm accelerometer may classify the activity appropriately. Although far fewer studies have been conducted using the wrist, one study compared the intensity classification accuracy of waist worn and wrist worn cut-points using the Gravity Estimator of Normal Everyday Activity (GENEA) activity monitor when compared to measured energy expenditure. Results showed the wrist worn cut-point (44.9% accurate) resulted in a greater ability to detect LPA when compared to the waist site cut-point (24.4% accurate) (140).

Commercially available activity monitors have become a popular trend for the public. While a number of the newer devices, such as the Jawbone™ or Fitbit™, have not been assessed for their accuracy in capturing light intensity activity, recent research has reported the utility of the Sensewear™ armband to measure in free-living conditions. The Sensewear™ armband mini uses multiple modes of information to estimate energy expenditure, including an accelerometer and measured skin temperature. The Sensewear™ mini was able to accurately discriminate between sedentary, light, and moderate activities greater than 85% of the 120 minute testing period when compared to measured energy expenditure (22). Additionally, the Sensewear™ mini showed greater percent intensity classification agreement compared to the measured energy expenditure than the Actigraph GT3X (51.1%) and ActivPal (68.9%).

Today, with the growing evidence indicating the importance of LPA in health outcomes, research investing in the development of better field measurement techniques for LPA is important. In order to fill this gap, both subjective and objective measurement devices should be developed and refined to fit the needs of multiple study designs and outcomes. Development of more accurate assessment tools to estimate time spent in light intensity will help to fully elucidate the full potential of light intensity activities for the benefit of health.

Types of Light Intensity Physical Activity

A common way to estimate physical activity intensities is to know what activity is being performed and use the average energy expended during the

identified activity as a measure of absolute intensity. Understanding the types of activities that are considered light intensity activities can help us understand where these LPA activities are most likely to be performed and by whom. LPA generally involves ubiquitous, everyday movements and activities, usually done for another purpose such as cooking, cleaning, or household walking. Most activities of daily living fit within the LPA intensity category, thus LPA transcends the full spectrum of activity domains: transport, household, occupational, and leisure time (Table 5) (3).

Table 5. Examples of Light Intensity Activities* from the Adult Compendium of Physical Activities (2)

Activity	MET Value
Transportation	
• Walking <2.5 MPH	2.0-2.8 METs
• Walking from house to house/from house to car/social walking	2.5 METs
Household	
• Household Walking	2.0 METs
• Cleaning General	2.5 METs
• Cooking, Food Preparation	2.0 METs
• Washing Dishes	2.5 METs
• Ironing	1.8 METs
Occupational	
• Active Workstation	2.3 METs
• Office or Lab Walking	2.0 METs
• Standing-Miscellaneous	1.8 METs
Leisure Time	
• Billiards	2.5 METs
• Wii	2.3 METs
• Light Calisthenics	2.8 METs
• Drawing, writing, painting	1.8 METs
• Standing – talking on the phone, text messaging	1.8 METs

*defined here as 1.5-2.9 METs

Light intensity activities are generally not performed with the intent of completing planned exercise to accrue some type of health or fitness benefit, although there may be some exceptions (e.g. slow walking). Because of the wide variety of activity types, and the utilitarian nature of these activities, the measurement of LPA is challenging, therefore information regarding the potential benefits of this activity intensity is lacking.

In an attempt to classify activity, not by intensity, but by purpose, the concept of non-exercise activity thermogenesis (NEAT) was introduced. "NEAT is the energy expended for everything we do that is not sleeping, eating, or sports-like exercise. It ranges from the energy expended walking to work, typing, performing yard work, undertaking agricultural tasks and fidgeting" (88). NEAT can include very low intensity activities through to vigorous intensity activities, but the majority of NEAT falls within the light intensity range. NEAT comprises most of our daily activity and energy expenditure, and has shown to be associated positively with health.

James Levine is the most prominent researcher in the area of NEAT and the benefits or consequences of the total amount of this accumulated activity energy expenditure. Levine's NEAT theory draws on the idea that physical activity energy expenditure provides the most variable (15-50%) source of energy expenditure, with resting metabolic rate and the thermic effect of food remaining a stable proportion throughout each day (89). He argues that since these types of activities provide the majority of our activity time, they demand attention in terms of environmental and biological influences of the activity time on the person and the person on the activity time. These are important points considering our non-

exercise, everyday activities have markedly decreased since the 1920's and this decline is evident in all domains of activities due to a variety of technological and environmental factors (29, 89). For example our jobs have become increasingly sedentary (20) because of the introduction of manufacturing and technology. Time spent in house work dropped 10% from 1965-1995 and overall caloric expenditure from household-work has largely declined due to advancements in labor-saving machines and other related technology (79). This decrease in non-exercising energy expenditure translates into lower total daily energy expenditure of the population and has contributed to the rise in prevalence of many chronic diseases (89).

Researchers have more specifically examined the effect of age on the role NEAT plays in total daily energy expenditure. Multiple studies have shown a decline in NEAT as one ages, with the NEAT energy expenditure in older adults being accounted for by much less time spent standing and walking and greater time spent sitting and lying when older adults are compared to younger adults (33, 49).

Since light intensity physical activity is the most variable proportion of our active day, developing a better understanding of LPA can help us begin to design strategies to increase our overall daily energy expenditure and therefore decrease chronic disease prevalence.

Identification of LPA type would be individually dependent and have the potential to vary greatly. As Howley pointed out in his classification of physical activity intensities, intensity is relative to a person's heart rate or maximal oxygen consumption therefore, how intense an activity is could be highly dependent on their age or fitness level (62). Additionally, individuals engage in activities at

different rates or paces when compared to others, such as housework and yard work. Therefore an activity that may be light intensity activity for one individual may be a moderate activity for another based on how they perform the activity. Further, the same activity, for instance walking, may be light intensity during some portions of the day and moderate intensity at another, depending on the purpose for walking and the environmental context in which the walking takes place (transportation versus occupational). For these reasons, the compendium of physical activity provides a nice beginning guideline to these activities for adults 20 to 60 years of age (3). However, a large hole in the literature exists as to what types of general activities, albeit relative based on self-selected pace, fitness level, health status, and age, constitute LPA in adults.

Prevalence of Light Intensity Physical Activity

There is a paucity of information specifically examining the prevalence of LPA; most studies have focused on moderate to vigorous intensity or time spent sedentary. Therefore, to obtain information on how much LPA the population engages in, inferences from moderate, vigorous, and sedentary behavior data need to be made.

In 2008, accelerometer-derived data from the 2003-2004 National Health and Nutrition Examination Survey (NHANES) revealed less than 5% of adults 20 years or older were meeting the United States physical activity (30 minutes per day of moderate intensity activity in 10 minute bouts on at least five days of the week) (134). Data from the Behavior Risk Factor Surveillance Survey which asks

participants questions regarding their leisure and household activities, reported that 45% of the United States population is meeting physical activity guidelines (121). While these two estimates show a 40% difference, they also both show that less than half of the Unites States population is engaging in the recommended amounts of MVPA to aid in the prevention or maintenance of many chronic diseases and other health benefits (137). Although the measurement tool may play a role in the estimated prevalence of physical activity level, there are additional consistencies in the prevalence of activity level throughout the population such as age and sex.

Age has been shown to influence physical activity and sedentary behavior levels. At age 20, the average American spends about 30 minutes of their day in MVPA and 350 minutes of their day in LPA (144). As one ages, the quantity of daily active time diminishes, with adults aged 60 years spending about 10 minutes of their day in MVPA and 225 minutes of their day in LPA (144). These data demonstrate the impact of aging on physical activity levels and that time spent in physical activity, of all intensities (light, moderate, and vigorous), is lessened (52, 134, 144). Additionally, these data highlight that while time spent in moderate and vigorous physical activities does decrease with age, individuals spend only 3% of their day in MVPA, with the other 97% in LPA and sedentary behaviors (115). While it is important to note that physical activity of all intensities decreases, it is also important to note that whatever the age, time spent in LPA and sedentary behaviors comprise the majority of the waking day (95-99%) (115). Studies have shown that on average, adults increase their time spent sitting by almost two hours from their 20's to their 70's (7.48 to 9.28 hours.day, respectively) (38, 102). There are gender

differences in the rate of decline of LPA as age increases. Men begin declining in time spent in LPA around age 45, while women maintain their LPA levels until about 60 years old (144).

The literature has consistently shown that men tend to engage in more MVPA than women, which remains consistent throughout the lifespan (134). Sedentary behavior also shows a gender influence, with men accumulating less sedentary time during their waking hours when compared to women until about age 50 when men and women's sedentary time begins to equate (102). The exact quantification of LPA decline between men and women across age has yet to be isolated. Using NHANES data Wolff et al. reported a 35% decline in percent of time spent in LPA for men and women from age 30 to 85 years (101, 144). These studies show that independent of age and gender we spend the majority of our day sedentary. When active time is examined the most variable portion of our active day comes from changes in LPA.

Data presenting activity profiles or information on movement patterns can be used to inform LPA prevalence rates. Loprinzi et al. looked at the movement patterns of United States adults from the NHANES add in years (2003-2004 or 2005-2006) study sample. Americans' movement patterns were grouped into three categories: those accumulating 1) greater than 150 minutes per week of MVPA and having a positive LPA-sedentary balance (meaning the amount of time spent in LPA was greater than the amount of time spent sedentary), 2) greater than 150 minutes per week of MVPA and a negative LPA-sedentary balance, 3) less than 150 minutes per week of MVPA and a positive LPA-sedentary balance, and 4) less than 150 minutes per week of MVPA and a negative LPA-sedentary balance. Results showed

that about half of the population engages in less than 150 minutes per week of MVPA and spends more time sedentary than in light intensity activity (93). In contrast only about 15% of the population accumulates greater than 150 minutes per week of MVPA with a positive light intensity to sedentary time balance. On average adults in the United States spend about 60% of their day sedentary with the next largest portion of their day spent in light intensity activity (37%), with time spent sedentary almost double the time spent in LPA (115).

Very few studies have reported the prevalence of light intensity physical activity in the population and no research has looked specifically at older adults LPA and their demographic and socioeconomic influence. Without this information, researchers, clinicians, and public health officials do not know the current prevalence of LPA and would not be able to track the progress or regress of LPA across the nation.

Light Intensity Physical Activity and Health

While much is known about MVPA and health, and more is being learned about sedentary behavior and health, little is known about LPA and health. Few studies have examined the relationship between LPA and health benefits and none have yet to elucidate the full potential benefits derived from engaging in an activity pattern high in light activity. Prior to 2007, LPA was indirectly studied through pedometry research. Pedometers pick up vertical movement from the hip as an act of stepping or striding with a final metric of step counts, but do not provide intensity information (142). Therefore, they provide an indication of the quantity of

ambulation would additionally pick up all ambulatory movements: LPA and MVPA. However, based on data presented earlier (144), only 3% of daily activity is in the range of MVPA, with the remaining activity being performed in the LPA range, suggesting that pedometers can provide an indication of LPA. Results of cross-sectional pedometer studies have indicated distinct relationships between the volume of daily steps accumulated and health outcomes (13, 135). Given that the majority of ambulatory activity is LPA, this research provides some of the initial insight into the relation between lower intensities and health.

In 1999, Lee and colleagues examined data from the Harvard Alumni Study looking at 13,485 men, and their risk of all-cause mortality when taking into account their weekly accumulate light intensity energy expenditure (84). Using the Paffenbarger questionnaire, authors' broke the sports/recreation activities into vigorous (>6 METs), moderate (4-6 METs), and light (<4 METs). Light activities included activities such as bowling, boating, and housekeeping. Results indicated there was no significant trend in light intensity energy expenditure dose-response to mortality in these men.

However, more recent epidemiological research from a group at the Karolinska Institute in Sweden followed over 3,500 men and women for 10 years to determine the effect of non-exercising activity on cardiovascular disease events and mortality risk (37). Each year, participants completed a questionnaire asking about lifestyle activities they performed on a regular basis. Three of the five activities on the questionnaire could be considered LPA (gathering berries, home repairs, car maintenance) according to the Compendium of Physical Activities (3). Participants

were categorized into tertiles based on their accumulated non-exercising physical activity. Results indicated that individuals within the highest tertile of non-exercising activity had a 30% lower risk of a cardiac event or death from all-causes compared to those in the lowest tertile of non-exercising activity. Those in the middle tertile had a 15% lower risk of a cardiac event and all-cause mortality compared to the lowest tertile. Although moderate activities were still included in this analysis, this study provides one of the first prospective epidemiological studies that specifically examined non-exercise activity. These studies provide evidence that epidemiologically speaking light intensity activities are an important component to take into account when analyzing an individual's physical activity behaviors. Future studies should continue to include light intensity activities to fully elucidate physical activities potential on our populations' health.

Healy and colleagues were one of the first groups to explicitly look at the cross-sectional relationship between accelerometer-derived LPA and two-hour plasma glucose response to an oral glucose tolerance test, an indication of the body's ability to uptake glucose post-prandial (54). Adults, aged 30 to 87 years, fasting blood glucose and oral glucose tolerance test values were measured during their first laboratory visit followed by a seven day accelerometer (Actigraph 7164) wear period to determine activity level. Activity data were categorized into three different sets of quartiles based on time spent in LPA, time spent sedentary, and time spent in MVPA. Results showed that there was a significantly lower two-hour plasma glucose in the quartile with the highest accumulated LPA (~6.4 mmol/L) versus the quartile with the lowest LPA (~5.2 mmol/L, p=0.006) with a similar

trend seen within the MVPA intensity quartiles (p for trend = 0.005). Additionally, after controlling for age, sex, height, waist circumference, accelerometer wear time, family and health history health risk factors, and MVPA, regression analysis revealed that light intensity physical activity was associated with a significantly lower two-hour plasma glucose response (β=-0.22, p=0.023). This study provided the initial empirical evidence that of a link between time spent in light intensity activity and blood glucose outcomes and began to draw attention to the potential health benefits from light intensity physical activity.

In 2010, Buman and colleagues examined the association between objectively measured LPA and overall self-rated health in older adults over 65 years of age (21). Eight hundred sixty-two older adults completed the health indicators from the Senior Neighborhood Quality of Life Survey and wore an Actigraph 7164 for seven days. Following division of LPA into "high-light" (defined by 1041-1951 counts/min) and "low-light" (defined by 100-1040 counts/min), there were significant, positive correlations between high LPA and physical health (r=0.40, p<0.001), and high LPA and psychosocial well-being (r=0.19, p<0.001). Significant positive correlations were also seen between low LPA and physical health (r=0.29, p<0.001), and low LPA and psychosocial well-being (r=0.12, p<0.001). Overall results showed that an increase in 30 minutes of high LPA was an associated 0.46 standard deviation increase in participants' physical health score, meaning higher levels of LPA in older adults resulted in greater self-reported overall health. No significant effect was seen in the low LPA. The distinction between the two LPA's were made in order to provide an older adult distinction between the low and high

ends of LPA which were hypothesized to have varying effects of health (28). Therefore, these data suggest it is possible lower levels of LPA are not attributable to favorable changes in overall self-reported health.

To date only a few studies have been published to extend these earlier findings. Green et al. investigated the association of LPA and cardiovascular disease risk factors in healthy women 20 to 39 years of age (46). A total of 50 women provided fasting blood samples. Blood was analyzed for triglycerides, high-density lipoprotein, low-density lipoprotein, total cholesterol, insulin resistance, high-sensitivity C-reactive protein, interleukin 6, tumor necrosis factor alpha, and adiponectin. Other cardiovascular risk factors were measured including waist circumference, body mass index, body composition, blood pressure, and peak oxygen consumption. Normal physical activity levels were measured over seven days using the Actigraph GT3X+ accelerometer and the Sasaki tri-axial cut-points (light intensity <2689 counts per minute) were used to determine intensity categories (122). Results indicated a significant relationship between time spent in LPA and triglycerides ($r=-0.44$, $p<0.01$), total cholesterol ($r=-0.29$, $p<0.05$), and homeostasis model assessment for insulin resistance ($r=-0.29$, $p<0.05$). These data support the hypothesis that a linear relationship exists between LPA and cardiometabolic risk factors and increasing the everyday activities (LPA) within our lives can play a large role in maintaining our health and preventing future chronic diseases.

A couple studies have utilized the open access NHANES data set, which contains a representative sample of United States adults, to explore the associations

between LPA or minimal activity and cardiometabolic biomarkers (61, 94). Howard and colleagues examined the association between accelerometer-measured time spent in light LPA (100-761 counts per min) and high LPA (762-1961 counts per min) and cardiometabolic biomarkers (61). Overall, individuals accumulated on average, 258±62.5 minutes per day of light LPA and 86.4±44.8 minutes per day of high LPA over a seven day monitoring period. Results indicated both light LPA and high LPA was significantly associated with more favorable biomarker values when adjusted for sociodemographic, behavioral, and health history variables (Table 6). Additionally, when results were adjusted to take into accounts time spent in MVPA results of the light LPA were not attenuated, however, the majority of the high LPA associations were diminished. These results provide evidence of a significant association between LPA and cardiometabolic biomarkers, similar to those seen with higher intensities of activity, albeit a greater magnitude of change (6, 61). Due to these favorable results, further exploration of optimal LPA dose-response by experimental, causal study designs are warranted.

Table 6. Association of LPA and Cardiometabolic Biomarkers

	Light LPA (β)	High LPA (β)
Waist Circumference (cm)	-0.92 (-1.56, -0.28)	-1.14 (-1.69, -0.58)
Body Mass Index (kg/m2)	-0.24 (-0.51, 0.02)	-0.28 (-0.52, -0.04)
Systolic Blood Pressure (mm Hg)	1.00 (1.00, 1.01)	0.99 (0.99, 1.00)
C-Reactive Protein (mg/dL)	0.92 (0.88, 0.96)	0.86 (0.81, 0.91)
HDL Cholesterol (mmol/L)	1.01 (1.00, 1.03)	1.02 (1.01, 1.03)
Triglycerides (mmol/L)	0.96 (0.94, 0.98)	0.96 (0.94, 0.98)

Plasma Glucose (mmol/L)	1.00 (1.00, 1.01)	0.99 (0.99, 1.00)
Insulin (pmol/L)	0.93 (0.89, 0.97)	0.87 (0.83, 0.92)
HOMA	1.07 (1.03, 1.11)	1.07 (1.03, 1.10)
2-Hr Glucose (mmol/L)	0.98 (0.95, 1.01)	0.96 (0.93, 0.99)

NS = non-significant

Futher extending the LPA prescription literature, Loprinzi et al. suggested the need for LPA guidelines for older adults by providing a comprehensive, objective understanding of the health benefits associated with accumulating LPA (94). The NHANES study sample was categorized based on their weekly-accumulated LPA, defined as 760-2020 counts per minute, into those who accumulated more than 300 minutes per week versus those who did not. Overall, Loprinzi and colleagues found that those who engaged in greater than 300 minutes per week of LPA had significantly more favorable health variables than those who did not. The variables associated with accumulated LPA included: body mass index (27.5 kg/m^2 (>300 min), 28.5 kg/m^2 (<300 min)), systolic blood pressure (134.2 mmHg (>300 min), 139.2 mmHg (<300 min)), waist circumference (98.8 cm (>300 min), 101.2 cm (<300 min)), triceps skinfold (18.6 mm (>300 min), 20.2 mm (<300 min)), C-reactive protein (0.32 mg/dL (>300 min), 0.51 (<300 min)), glucose (107. 3 mg/dL (>300 min), 113.5 mg/dL (<300 min)), insulin resistance (2.7 (>300 min), 3.7 (<300 min)), glycosylated hemoglobin (5.65% (>300 min), 5.88% (<300 min)). These differences among groups mirrored the same differences in health variables seen when the study sample was split by accumulated MVPA (>150 minutes versus <150 minutes per week). While there were significant improvements in risk factors seen

with >300 minutes per week versus <300 minutes per week, the 300 minute cut-off was somewhat arbitrarily chosen; chosen only to mimic MVPA recommendations. Therefore, additional research should be done to determine specific dose-response. However, one important finding to note was the symmetry seen in variable differences between the LPA and MVPA recommendations. This suggests the accumulation of LPA may provide similar health benefits as higher intensities.

Recently, substitution techniques have been used to examine the effect of substituting sedentary behaviors with more active behaviors monitored over a seven-day physical activity monitor monitoring period. Healy et al. found, in a sample of 279 overweight/obese adults with type 2 diabetes, substituting 30 minutes of prolonged sitting time (>30 minutes in duration) with 30 minutes of LPA resulted in a significant -0.61 unit change (95% CI, -1.46 to 0.08) in waist circumference and -0.29 unit change (95% CI, -1.33 to -0.22) in body mass index (56). There was no significant change seen in fasting plasma glucose, or an any variables when LPA was substituted for non-prolonged sitting time (<30 minutes in duration), or MVPA was substituted for non-prolonged or LPA.

Similarly, Matthews et al. were more specifically interested in the effect of replacing one hour of overall sitting time with different types of activities (103). In the older adults studied, the authors' found those who were less active (defined as spending less than 2 hours per day in overall activity) the adjusted hazard ratios (95% CI) for mortality risk when replacing one hour of sitting with household chores, lawn and garden, or daily non-exercising walking were 0.80(0.74-0.86), 0.49(0.43-0.56), and 0.66(0.57-0.78), respectively. There were no significant effects

seen when substituting these activities for one hour of sitting time in the more active group (those who spend greater than 2 hours per day in overall activity).

Evidence presented indicates a positive association between LPA and glucose control (54), cardiovascular disease risk factors (46, 94), and all-cause mortality (37). While the study evidence to this point is limited, the positive results from these studies provides rationale to continue uncovering the benefits of light intensity physical activity, in addition to investigating the causation effect of LPA on different health outcomes through intervention-based study designs. The reviewed literature has provided a beginning foundation showing there is a relationship between light intensity and health benefits however, there are large gaps in understanding optimal volume of LPA, bouts of LPA, types of light intensity physical activity, and the associated benefits for each unit of prescription. In order to further extend this area of inquiry these gaps in knowledge need to be filled.

Experimental Studies

To date, there have been few intervention studies to assess the causal link between light intensity physical activity and the resultant health benefits. The few intervention studies can be divided into acute interventions where in the focus was on the immediate effect of a light intensity exercise bout on a biomarker, or a long-term effect where the intervention occurred over a few days or months to elicit an adaptation type change. Overall, of the existing literature, studies suggest an improvement in the measured health variable of interest with an increase in LPA.

Acute Interventions

Previous research has not explicitly focused on the immediate effects of LPA on cardiometabolic biomarkers. However, a few studies have examined the changes seen in metabolic response when LPA was used as the stimulus to disrupt sedentary behavior. In general, the following studies report a breaking up long bouts of sedentary behavior with a bout of LPA elicits positive health impact/outcome in adults.

Bailey et al. examined the effect of standing breaks or light intensity walking breaks on cardiometabolic biomarkers (plasma glucose, total cholesterol, high density lipoprotein, triglycerides, systolic and diastolic blood pressure) when compared to a sitting condition over a five hour period (7). Ten young adults (24.0±3.0 years) underwent three separate conditions separated by at least six days. The three conditions were 1) uninterrupted sitting, 2) sitting with standing breaks for two minutes every 20 minutes, and 3) sitting with a two minute light intensity break every 20 minutes (10% (30 min) total time in LPA). Test meal was provided at the start of the measurement period and blood samples were drawn every hour. Results showed there was a significant decrease in plasma glucose area under the curve between the sitting condition (22.0 mmol L/5-h) and the light intensity breaks (20.0 mmol L/5-h) condition (-2.0 mmol L/5-h or - 15.9%, $p<0.001$) and the standing breaks (22.2 mmol L/5-h) and light intensity breaks (-2.2 mmol L/5-h or -16.7%, $p<0.001$). However, there was no condition effect seen for blood pressure, total cholesterol, triglycerides, or high-density lipoproteins. These results indicate there is benefit to breaking sedentary time, however, changing posture may not be enough of a stimulus to change cardiometabolic biomarker response. Instead, when

decreasing sedentary times and increasing sedentary breaks, adding a LPA component could provide a greater metabolic effect.

Similarly, Dunstan et al. looked at post-meal glucose and insulin response, but over seven hours and in 19 overweight or obese middle-aged adults (35). Participants completed three conditions 1) uninterrupted sitting, 2) sitting with a two minute light intensity break every 20 minutes (10% (42 min) of total time in LPA), and 3) sitting with a two minutes moderate intensity break every 20 minutes. For all conditions, participants sat for the first two hours of testing, then consumed a test meal. Blood samples were taken every hour over the seven-hour period. When the light intensity condition was compared to the sitting condition, results showed a significantly lower plasma glucose area under the curve with the LPA (24.1% or 5.2 mmol/hr difference, $p<0.01$). Similarly, the moderate intensity condition also showed a 29.6% (4.9 mmol/hr, $p<0.01$) lower plasma glucose area under the curve when compared to the sitting condition (6.9 mmol/hr). In both conditions the mean insulin area under the curve was 23% lower ($p<0.0001$) for the break conditions (light and moderate) when compared to the sitting condition. Interestingly, there were no significant differences seen between the glucose or insulin responses to the light and moderate intensity conditions, suggesting the glucose and insulin response to moderate activity is similar to the response elicited from LPA. Therefore, LPA may be as beneficial to glucose and insulin dynamics when compared to moderate intensity activity.

Collectively, these studies show there is an immediate response of cardiometabolic factors, specifically glucose and insulin, to light intensity activity

when compared to uninterrupted sitting conditions. These findings provide clout for the promotion of light intensity activity as an intervention agent in improving cardiometabolic health in adults. Additionally, these studies provide evidence LPA shows an equal effect on glucose response when compared with moderate intensity activities, providing influence to developing LPA recommendations as a means to enhance health. There are still many gaps to be filled within the study of health benefits due to LPA including determining the optimal duration of LPA bouts, the frequency to which these LPA bouts should occur, or the types of light intensity activities that will elicit these benefits considered, and whether the effect of LPA will be similar across age, gender, fitness level and health status

Long-Term Interventions

LPA has shown to provide acute changes in health indicators. The next step in dissemination of light intensity as an activity prescription would be determining whether engaging in light intensity physical activity (and how much light intensity activity) over a prolonged period of time would translate into an improved health profile. Assessing the effect of habitual bouts of LPA is necessary in order to measure potential chronic adaptations that may occur as a result of the activity performed. To date, only two studies have looked at longer-term effects of LPA on health outcomes. Duvivier et al. examined three different week-long activity patterns in 18, healthy, young adults (21±2 y), finding a significantly decreased insulin area under the curve when 6 hours of walking and standing was compared to a completely sedentary condition (36). In contrast, Herzig et al. was interested in the changes in cardiometabolic biomarkers following a three-month light intensity

physical activity intervention in 78, overweight, middle-aged (58.8±10.4 y) adults, again seeing a significant decrease in insulin fasting and 2-hour post-load insulin at three-month follow-up (59).

Dunvivier et al. manipulated participant activity profiles for 7 continuous days over three different conditions: 1) sitting condition which consisted of 8 hours/day of sleeping, 14 hours/day of sitting, and 1 hour/day of both standing and walking, 2) minimal intensity condition which replaced 6 hours of sitting with 4 hours of walking and 2 hours of standing per day, and an 3) exercise condition which replaced one hour of sitting with one hour of vigorous activity (36). Each condition was followed for one week with glucose, insulin, and cholesterol measurements taken pre- and post-conditions. Total daily energy expenditure was significantly higher ($p=0.022$) in the minimal activity condition when compared to the exercise condition (2486 versus 2407 kcals/day), although not a large meaningful difference unless extrapolated over a longer period of time, such as a year, which could play a large role in overall energy balance (60). Total sitting time was significantly different between all conditions, with the minimal activity condition spending the least amount of time sitting (7.4 hrs), followed by the exercising condition (12.7 hrs), and finally the seated condition (13.6 hrs). The oral glucose tolerance test insulin area under the curve was significantly less after the minimal activity condition (6727.3 mU min/ml, $p=0.010$) when compared to the exercise condition (8320.4 mU min/ml, $p=0.002$) and sitting condition (7752.0 mU min/ml). There were no condition differences seen for glucose. Triglycerides also showed a between condition difference with the minimal activity condition showing

a decreased triglyceride concentration (0.70 mmol/L) when compared to the sitting condition (0.90 mmol/L) and the exercise condition (0.85 mmol/L), which were not significantly different from one another. This study showed that spending more time in LPA type activities resulted in greater manipulation of cardiometabolic variables than a single shorter bout of MVPA.

Herzig et al. prescribed three months of light intensity physical activity to 78 sedentary, overweight adults with abnormal glucose tolerance. The intervention consisted of 45-minute slow (3-4 km/hr) walking sessions with a stretching-focused warm-up and cool-down, three times per week (59). At follow-up, the intervention group recorded a significant decrease in fasting and 2 hour insulin (baseline 18.7 mU/L, decreased 3.4 mU/L, p=0.035; baseline 116.9 mU/L, decreased 26.6 mU/L, p=0.003), homeostasis model assessment-estimated insulin resistance (baseline 5.7, decreased 1.1, p=0.003), total plasma cholesterol (baseline 5.3 mmol/L, decreased 0.3 mmol/L, p=0.041), low-density lipoproteins (baseline 3.0 mmol/L, decreased 0.4 mmol/L, p=0.008), and visceral fat area (baseline 163.7 cm^2, decreased 5.5 cm^2, p=0.030) when compared to changes seen in the control group. This study suggests LPA is a beneficial means to both greatly time spent active in adults but that light intensity elicits enough of a stimulus to see significant health-related changes over three months.

There is much work left to be done in order to determine the long-term effect LPA could have on health. Herzig et al. (59) provides a great example of a successful LPA exercise intervention during a single continuous bout. However, one of the benefits to LPA is the freedom of the participant to engage in LPA throughout their

day outside of an exercise bout considering the large amount of LPA that falls within everyday activities. The current research should be extended in the future to understand the health and sustainability implications of bouted LPA. Future research should examine home-based or physical activity based interventions to increase the feasibility and sustainability of these active lifestyles. Answering many of the previous knowledge gaps identified will provide needed rationale to design an appropriate and effective long-term intervention to elicit both a sustainable behavior change and improved disease risk profile. If evidence is strong for obtaining health benefits from chronic exposure to a light intensity stimulus, and increasing light intensity physical activity proves to be more self-efficacious, then allocating more resources towards these interventions to increase LPA will be warranted in the future.

Conclusion

In summary, LPA is often overlooked as a viable movement option for increasing population health in an easily attainable manner. The reviewed cross-sectional studies have preliminarily shown an association with LPA and health outcomes including metabolic and cardiovascular health. Further, some interventional research has provided initial evidence that increasing LPA can have acute beneficial effects on cardiometabolic biomarkers. While this area of research is in its infancy, this provides a multitude of research gaps that should be explored. Understanding current levels of LPA and how and where LPA is accumulated in the older adult population will help us understand the public health effect that using LPA as an interventional strategy could have on our older adult population.

Additionally, examining the optimal quantity of LPA to elicit health benefits will provide much needed evidence to the development of a LPA guideline for health benefits. The long-term goal of this dissertation is to lay the foundation that increasing LPA in adults and older adults will decrease the growing number of chronic diseases in the population and could greatly increase their quality of life, decrease their years of morbidity, and their overall risk of mortality.

CHAPTER 3: LIGHT INTENSITY PHYSICAL ACTIVITY AND HEALTH IN ADULTS: A REVIEW

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Running Head: Light intensity physical activity and health

Abstract

Background: To date, little research has explicitly focused on the relationship between light intensity physical activity (LPA) and health outcomes. Emerging research suggests there may be a benefit to engaging in lower intensity physical activities, independent of time spent in MVPA. **Objective:** The purpose of this systematic review was to critically examine the current state of knowledge pertaining to LPA and the benefits of LPA to health in adults. Specifically this review focuses on LPA and: 1) all-cause mortality, 2) metabolic health, 3) cardiovascular health, 4) cancer risk, and 5) functional health. **Methods:** Following a Pubmed and Sportdiscus database search, 55 studies were included with all study designs considered. Pre-determined search terms, using MESH terms "sedentary lifestyle," and "exercise," with keywords "light intensity," "low level," and "low intensity." Additionally, the Filter: "Adult: 19+ years" was applied to the results. Studies were included if they were peer-reviewed, published in the English language, participants studied were 20 years of age or older, and able-bodied. Additionally studies had to include an outcome measure of all-cause mortality, metabolic, cardiovascular, cancer, or function. Excluded studies included published books, abstracts, conference proceedings, theses, dissertations or unpublished works and resistance-training studies. Three reviewers independently scored study quality using the Quality Criteria Checklist for primary research articles presented in the American Dietetics Association Evidence Analysis manual, which included a risk of bias rating. Extracted information included study design, outcome variables, eligibility criteria, study protocol, outcome measurements, demographics, and study results. **Results:**

The majority of the studies used objective physical activity assessments (79%) with no consistency in defining or classifying LPA. Results of this systematic review determined that LPA is positively associated with all-cause mortality, glucose, insulin, insulin resistance, c-reactive protein, metabolic syndrome, physical function, and cognition; has no relationship with LDL or total cholesterol; and there is insufficient evidence to support an association on body mass, BMI, waist circumference, body composition, HbA1c, blood pressure, HDL, triglycerides, cancer risk, VO_{2max}, and arthritis. **Conclusions:** The strongest associations tended to be in generally inactive populations (older adults, adults with chronic disease). These groups represent an important target population for increasing activity levels. Identified limitations in the current literature set include inconsistencies and imprecision in the measurement and classification/definition of LPA, lack of appropriate comparison groups, and the need for more intervention work, since interventions are lacking. The preliminary evidence supports continued research to determine the full benefit of LPA with the potential for addition to future national physical activity guidelines.

Introduction

Since the 1950's and the seminal work of Dr. Jeremy Morris, the benefits of physical activity have been the focus of many researchers and practitioners around the world (112). Much of the early work focused on understanding the benefits of physical activity of higher intensities, namely moderate-to-vigorous activity (MVPA) the majority of which is performed as exercise. With the growth of knowledge about the benefits of physical activity, and movement in general, great interest grew in the effect of overall physical activity accumulated (any movement that results in energy expenditure), as opposed to the single dimension of exercise, as a planned and structured activity for the purpose of increasing fitness. While much attention has been paid to MVPA, increased interest has grown in lower intensity activities, however little research has explored the health benefits of light intensity physical activity (LPA).

In general, LPA include everyday activities and may fall in any activity domain, such as household activities, slow walking, walking as the result of completing other tasks such as cleaning, or low-level leisure-time activities. LPA is defined as metabolic equivalent (MET) values greater than one and one-half and less than three (3, 123), the intensity in-between moderate intensity activity and sedentary activities. Adult prevalence data has shown 30% of the waking day is spent in active behaviors with LPA making up 79% of that active time (115). To date, little research has examined the role of LPA as a critical portion of our daily movement and little attention has been given to changes in health associated with an increase or decline in LPA over the life course.

There is preliminary evidence supporting a link between LPA and health (11, 21) no study has sought to review the specific health implications of LPA. Therefore, this systematic review seeks to fill this knowledge gap by reviewing the current state of knowledge on LPA and benefits to health in adults, more specifically discussing: 1) all-cause mortality, 2) metabolic health, 3) cardiovascular health, 4) cancer risk, and 5) functional health.

REVIEW: Methods

Search Strategy

Two databases were searched: Pubmed and SportDiscus (searched October 2015). Searches were done using MESH terms "sedentary lifestyle," and "exercise," with keywords "light intensity," "low level," and "low intensity." Additionally, the Filter: "Adult: 19+ years" was applied to the results. Initial search results on Pubmed and Sportdiscus returned 2141 and 317 articles, respectively. Initially titles and abstracts were reviewed for relevance to the intended purpose. This narrowed the search results down to 56 articles. Finally, authors were asked to add any relevant articles they were aware of that were not included on the search list. Authors added an additional 10 articles, for a total of 66 articles included in the initial review by all authors. A diagram of article selection is shown in Figure 1.

Study Selection

Studies were included into the review process if they were peer-reviewed, published in the English language, participants studied were 19 years of age or

older, and able-bodied. All study designs were considered for inclusion and primary outcome measures included in review process were all-cause mortality, metabolic, cardiovascular, cancer, or functional outcomes. Studies that were excluded were published books, abstracts, conference proceedings, theses, dissertations or unpublished works. In addition, resistance-training studies were excluded since the physiological mechanisms underlying health-related changes may differ between aerobic and resistance training.

Data Extraction & Quality Assessment

Three independent reviewers (authors) read each selected article and extracted information relevant to the review. Extracted information included study design, outcome variables, eligibility criteria, study protocol, outcome measurements, demographics, statistical analysis, confounders measured, and study results specific to LPA. Reviewers independently scored study quality using the Quality Criteria Checklist for primary research articles presented in the American Dietetics Association Evidence Analysis manual, which included a risk of bias rating (4). All studies included in the review received a "positive" rating for study quality from all three reviewers. The "positive" rating indicated the answers to the checklist's validity questions were "Yes," as opposed to if any answers were "no" to the study validity questions, the study would be classified as "neutral" or "negative."

Results

Overall, 55 studies were included for final review and synthesis. Sixty-one percent of the studies reviewed were cross-sectional, 15.8% were experimental, 8.8% longitudinal, and 7% interventions. Other study designs included prospective observational (n=1), case-control (n=2), and retrospective (n=1). Of the 55 studies included, 16 studies had a primary outcome of LPA including 12 cross-sectional studies, three experimental, and one intervention (Supplemental Table).

The measurement of LPA differed between studies with 43 of all studies using objective physical activity assessments, with 22 of those studies using an Actigraph hip-worn accelerometer (models 7164, GT1M, GT3X, GT3X+), three using activPal, two using Sensewear armbands, two using the IDEEA monitor, two using Actical, and two that used heart rate. Other objective monitor types used included ActiMarker, HJA-350IT Omron, physical activity monitor suit, and Newtest.

In addition to different methods of physical activity measurement, different definitions of LPA were used throughout the reviewed literature. Out of the studies that used a uniaxial Actigraph activity monitor, 30% classified LPA as 100-1951 cpm, 17% classified LPA as 100-2020 cpm, and 7% used 100-759 cpm to classify LPA. Ten percent of the studies broke the LPA spectrum into a low light intensity (100-759 cpm) and a high light intensity (760-1952 cpm or 2020cpm). Finally, one study used a LPA cutpoint of 200-1999 cpm, while one used individual participant cutpoints. Only one triaxial Actigraph was used and LPA was classified as 150-2688 cpm.

When physical activity classification was dependent on MET values, MET intensity classification for LPA ranged as well. Out of the five studies that classified

LPA based on energy expenditure, three defined LPA as 1.5-2.99 METs, one defined LPA as 1.1-2.9 METs, and one defined LPA as 1.6-2.9 METs.

All-Cause Mortality

Three of the reviewed studies had a primary outcome of mortality. The earliest of the three, Lee et al. reported in 2000 there were no trends in decreased mortality risk when examining energy expended (kj/wk) through light intensity exercise (84). The other two studies both report LPA was associated with decreased risk of premature death, showing a 27% (95%CI: 0.53, 0.93) decrease in risk of all-cause mortality with high non-exercise physical activity (37) and a 30% decreased risk in men and 50-60% decrease in risk of mortality in women with one to two hours per day of non-exercise activity (103). Overall, these data suggests there may be a relationship between time spent in non-exercise physical activity and a decreased risk of premature death, however, at the current time the evidence is weak (Table 7).

Metabolic Health

Body Mass: Four cross-sectional studies reviewed included body mass as an outcome variable. Cross-sectional research showed a significant inverse relationship between body mass and LPA. Two studies showed significantly lower body mass in men and women with increasing frequency and duration of LPA (9, 90). However,

Littman et al found this relationship may only exist in lower BMI classifications (<25 female, <30 male) in a sample of 53-57 year olds (90).

Two intervention studies measured body mass as an outcome variable. Following a one-year workplace treadmill desk intervention, participants who were obese lost 2.3±3.5 kg ($p<0.03$) post-intervention and increased their LPA by 63% (74), while no decrease in body mass was seen in lean participants. Herzig et al. found a significant decrease in body mass (pre: 92.4±19.4 kg, post: 91.5±20.3 kg) following a 3-month LPA walking intervention in middle-aged adults, however there were no significant differences in change in mass between intervention and control groups (59).

Cross-sectional studies reveal mixed results. However, intervention studies have shown statistically significant decreases in body mass following a LPA intervention, therefore, LPA may provide a sufficient stimulus to decrease body mass, suggesting there may be a relationship between LPA and body mass however the evidence at this point is weak (Table 7). Further research should seek to understand the optimal duration and time needed for these changes to occur.

Body Mass Index: Eleven cross-sectional studies reviewed examined the effect of LPA on body mass index (BMI) with mixed results, seven showing significant beneficial relationships between BMI and LPA, and five reporting no significant relationship. Regression analyses reported β ranging from -0.01 (95% CI: -0.01, -0.004) to -0.41 (95% CI: -0.61, -0.22) with the greatest effect seen in a (30-80 yr) diabetic population (40, 95). Correlation values ranged from $r=-0.26$ ($p<0.001$) in a

population of diverse older adults to r=0.53 (p<0.001) when BMI is correlated with standing time in middle-aged pre-bariatric patients (78, 131). Finally, Loprinzi et al. reported a significant 1.0 kg/m^2 difference in older adults from NHANES who accumulate 300 minutes per week of LPA and those who accumulate less than 300 minutes per week of LPA (94). To date there have been no identified intervention or experimental studies that examined change in BMI. Due to the mixed results, there is currently insufficient evidence to make a conclusion of the effect LPA can have on BMI (Table 7).

Waist Circumference: Fifteen cross-sectional studies reviewed included waist circumference as an outcome variable. Again, there were mixed results of the benefit of LPA to healthy waist circumference with seven studies reporting significant relationships and eight studies reporting no significant relationship. Older adults from NHANES were divided into two groups based on the amount of time they spent in LPA (<300 minutes per week versus >300 minutes per week). Waist circumference results revealed a significant difference between the two groups (<300 min: 101.2cm; >300 min: 98.8cm) (94). Swartz and colleagues reported a significant negative relationship between waist circumference and time spent in LPA (r=-0.292, p<0.001) in a diverse older adult population (131). Finally, regression analyses ranged from β=-0.01 to β=-4.362 change in waist circumference, with each one hour increase in LPA (95, 98). The largest change in waist circumference with increasing LPA was reported in a population of breast cancer survivors after adjusting for age, education, and energy intake (98). To date

there have been no identified intervention or experimental studies that examined change in waist circumference. Due to the mixed results, there is currently insufficient evidence to make a conclusion on the relationship between LPA and waist circumference (Table 7).

Body Composition: Seven cross-sectional studies examined a measure of body composition, with four reporting significant associations between time spent in LPA and body composition and three reporting no relationship between the variables. Measurement of body composition varied with three studies using dual-energy x-ray absorptiometry, one using computerized tomography, one using bioelectrical impedance analysis (BIA), and one using tricep and subscapular skinfolds. Correlation analyses showed significant ($p<0.05$) relationships between body fat percent and LPA, ranging from $r=-0.06$ in Mexican American adults to $r=-0.42$ in middle-aged women (45, 119). When males and females were analyzed separately the beneficial effects on body composition were stronger in males ($\beta=-0.19$ total abdominal adipose tissue, $p=0.02$, $\beta=0.30$ visceral adipose tissue, $p=0.03$) than in females (no significant relationship) (125). One physical activity intervention study examined change in body composition following a three-month LPA walking intervention in middle-aged adults reporting no significant change in body composition post-intervention, when measured by BIA. Due to the mixed results, there is currently insufficient evidence to make a conclusion of the effect LPA can have on body composition (Table 7).

Glucose: Twelve cross-sectional studies reported an outcome measure of glucose with only two finding significant relationships between glucose and LPA. Howard et al. explored the effect of "high-light" (accelerometer-derived cpm 760-1951) physical activity, or the upper half of the LPA spectrum, and found a significant association with glucose (β=0.99 (95%CI: 0.99, 1.00)) after controlling for socio-demographic, behavioral, and medical covariates in adults (61). The second study to report a significant relationship between LPA and glucose was conducted in a diabetic population, reporting a significant trend in decreased 2-hour plasma glucose as LPA increased (p=0.006) as well as revealing a -0.22 mmol/l (p=0.23) change in glucose values with every one hour increase in LPA (54). These results suggest LPA may provide a sufficient stimulus for beneficial impact on plasma glucose in diabetic populations, however, the benefit LPA may provide for a healthy population may warrant further research.

Five experimental studies examined the effect of LPA on glucose levels (7, 35, 36, 81, 97). In a five hour trial, Bailey and colleagues found that when young adults engaged in a two minute bout of light intensity walking every twenty minutes, the glucose area under the curve (AUC) was significantly lower (p=0.001) post-prandial (mean AUC 18.5 mmol/l/5-h (95% CI: 17.0, 20.0)) than when compared to a uninterrupted sitting condition (22.0 mmol/l/5-h (95% CI: 20.5, 23.6)) and a condition where participants stood for two minutes every twenty minutes (22.2 mmol/l/5-h (95% CI: 20.7, 23.7)) (7). Similarly, Dunstan et al. found a significantly lower glucose AUC for a two minute LPA walking break every twenty minutes (5.2

mmol/l (95% CI: 4.1, 6.6)) than the uninterrupted sitting condition (6.9 mmol/l (95% CI: 5.5, 8.7)) over five hours in overweight/obese adults (35). Larsen et al. expanded on these previous studies by extending the observation time and observing the effect these two-minute LPA breaks every twenty minutes had over three days in free-living overweight/obese adults. Their results reported a sustained effect on decreasing glucose over three days compared to a completely sedentary condition, however there was sustained effect (81). Finally, Lyden and colleagues asked young, active participants to decrease their time spent in LPA (97). Results revealed a significant change in glucose when LPA was restricted (decreased time in LPA about 88 minutes/day) over seven days (β=-4.89, p=0.05)

One randomized control trial tested the effect of increasing LPA on two-hour post-load glucose in middle-aged adults (59). Their results reported no significant change in glucose response following a three-month LPA walking intervention.

These findings help confirm the previous submission that LPA may be beneficial to a diabetic or overweight/obese, at-risk population, by increasing uptake of glucose (Table 7). However, due to less beneficial association seen in the cross-sectional and long-term intervention study design, as compared to the short-term experimental study conditions, this suggests the beneficial effects may be acute and not sustained.

HbA1c: Four cross-sectional studies were reviewed that measured HbA1c. There were no significant associations between glycosylated hemoglobin and LPA. Loprinzi et al. reported a significant difference in HbA1c percent in older adults

from NHANES that accumulate >300 minutes per day of LPA (5.65%) and those that accumulate <300 minutes per day of LPA (5.88%) (94). However this difference is small, therefore, further research should be done to determine if this result is reproducible (Table 7). To date there have been no identified intervention or experimental studies that examined change in HbA1c in response to LPA.

Insulin: Nine cross-sectional studies examined insulin as an outcome variable, with one-third reporting significant negative associations between insulin and LPA. All significant results were from regression analyses that ranged from an association of insulin change (β=0.87, 95% CI: 0.83, 0.92) with an increase of about 45 minutes of high-LPA in adults from NHANES to an association of insulin change LPA (β=-0.276, 95% CI: -0.483, -0.069) with a one hour increase in breast cancer survivors (61, 98).

Three experimental studies reviewed included insulin as a measured outcome with two studies revealing that LPA elicited beneficial results. Dunstan et al. found significantly lower postprandial insulin AUC ($p<0.001$) during the LPA breaks condition (633.6 mmol/l (95% CI: 552.4, 727.1)) when compared to the uninterrupted sitting condition (828.6 mmol/l (95% CI: 722.0, 950.9)) over five hours in overweight/obese adults (35). Larsen found these effects are then sustained when the intervention is carried out over a three-day period in middle-aged adults (81).

One randomized control trial measured insulin, following a three-month LPA walking intervention in middle-aged adults at high risk for diabetes (59). Results revealed a significant difference in two-hour post-load insulin response between the

intervention and control group post-intervention (difference 26.6 mmol/l (95% CI: 1.1, 51.8).

While only 33% of the cross-sectional studies reviewed report a significant relationship between insulin and LPA, the majority of the experimental studies and the only intervention study show a positive benefit. Therefore, it is shown LPA may have a positive impact on insulin, especially when baseline insulin values are elevated (Table 7).

Insulin Resistance: Five cross-sectional studies discussed insulin resistance as an outcome variable with four reporting significant associations between insulin resistance and accumulated LPA. A correlation of $r=-0.29$ ($p<0.05$) was reported in a study of 20-39 year old women (46). Further a regression analysis in Japanese older adults reported a significant -0.125 (95% CI: -0.001, -0.0002) change in HOMA-IR with a one minute increase in LPA, after adjusting for age, sex, waist circumference, and MVPA (44). Similarly, Loprinzi et al. showed a 1% difference in HOMA-IR in an older adult NHANES population between those that accumulate >300 minutes per week of LPA and those that do not (94). To date there were no identified intervention or experimental studies that examined change in insulin resistance in response to LPA. Results indicate there may be benefit to improved insulin resistance with increasing LPA, however the current evidence is weak (Table 7).

Cardiovascular Health

Blood Pressure: Seven cross-sectional studies measured blood pressure and it's association with LPA. Two studies reported significant associations between the two variables. Both studies were secondary data analyses from NHANES with one reporting a 1.00 mmHg (95% CI: 1.00, 1.01) change in systolic blood pressure with each 62.5 min change in low-LPA (accelerometer-derived cpm 100-759) in adults (61). The second reported a lower cross-sectional systolic blood pressure in older adults accumulating >300 minutes per week of LPA (134.2 mmHg) compared to those with <300 minutes per week of LPA (139.2 mmHg) (94).

Three experimental studies and one randomized control trial measured blood pressure following a LPA bout (34, 82, 129, 138). Larsen et al. found a significant effect for differences in systolic and diastolic blood pressure when LPA was performed (2 minutes of walking every 20 minutes) over a five-hour period, compared to a seated condition in adults with hypertension (82). The remaining three studies did not report any significant effects of LPA on systolic or diastolic blood pressure. Due to the mixed results, there is currently insufficient evidence to make a conclusion of the effect LPA can have on systolic and diastolic blood pressure or LPA may have no impact (Table 7).

High Density Lipoprotein (HDL): Eleven cross-sectional studies were reviewed with an outcome measure of HDL, with one study finding a significant 1.02 mmol/l (95%CI: 1.01, 1.04) increase in HDL with each 44.8-minute increase in high-LPA. The remaining studies found no significant association between HDL and LPA.

One experimental study measured HDL, when comparing a 5-hour uninterrupted sitting condition to breaking up the 5-hour sitting condition with two minutes of light intensity walking every twenty minutes (7). No significant effect was seen on HDL following the 5-hour LPA trial. To date, there is currently insufficient evidence to reach a conclusion of the effects LPA on HDL or LPA may have no impact (Table 7).

Low Density Lipoprotein (LDL): Five studies included LDL as a measured outcome with none presenting a significant relationship between LDL and LPA. One randomized control trial in middle-aged adults at risk for developing diabetes reported significantly lower LDL values following a three-month LPA walking intervention when compared to the control group (difference 0.4 mmol/l (95% CI: 0.1, 0.7) (59). To date there have been no identified experimental studies that examined change in LDL. These cross-sectional and intervention results suggest LPA may not alter LDL in adults and older adults (Table 7).

Triglycerides: Twelve cross-sectional studies reviewed measured triglycerides and LPA with one-fourth of the studies reporting a significant change in triglycerides with change in LPA. Correlation analysis revealed there was a moderate relationship between LPA and triglycerides ($r=0.44$, $p<0.01$) in young (20-39 year old) women (46). Regression analyses from NHANES data in adults found small changes in triglycerides with increases in LPA ($\beta=0.96$ mmol/l (95% CI: 0.94, 0.98) and log-$\beta=0.04$ ($p<0.05$)) (61, 99).

Two short-term, experimental studies examined the effect LPA has on triglycerides, comparing a prolonged seated condition to a prolonged seated condition with two minute LPA walking breaks every 20 minutes in middle-aged adults (7, 81). Neither study found any significant change in triglycerides with the LPA walking stimulus. There is currently insufficient evidence to make a conclusion of the effect LPA may have on triglycerides (Table 7).

Total Cholesterol: Three cross-sectional studies reported a measure of total cholesterol with one of the studies revealing a significant relationship between total cholesterol and LPA, $r=0.29$ ($p<0.05$), in young women (46). One experimental study examined the effect breaking up five hours of uninterrupted sitting in non-obese adults with two minutes of light intensity walking every 20 minutes had on total cholesterol (7). Results indicated there were no significant effects of LPA on total cholesterol. To date there have been no identified intervention studies that examined change in total cholesterol with an increase in LPA. There is currently insufficient evidence to make a conclusion of the effect LPA can have on total cholesterol but the evidence thus far is suggesting there may be no impact (Table 7).

C-Reactive Protein: Four studies reviewed examined the association between c-reactive protein and LPA, with three finding significant associations. All were regression analyses and examined adult data (20 years and older) from NHANES. Howard et al. found significant relationships for both high LPA ($\beta=0.92$ mg/dL per 62.5 minutes, 95%CI: 0.88, 0.96) and low LPA ($\beta=0.86$ mg/dL per 44.8 minutes,

95%CI: 0.81, 0.91) (61). Maher et al. found a significant log-β=-0.06 ($p<0.05$) (99). Finally, there was a significant difference reported when older adults in NHANES who accumulate >300 minutes per week of LPA (0.32 mg/dL) were compared to those who accumulate <300 minutes per week (0.51 mg/dL) (94). Results indicated that LPA is significantly associated with c-reactive protein, however, the current evidence is weak (Table 7).

Metabolic Syndrome: Two studies looked at the relationship between diagnosis of metabolic syndrome and LPA. Both revealed a significant trend in decreasing incidence of metabolic syndrome with increasing time spent in LPA. Healy et al. found that in Australian adults there was a significant β=-0.20 (95% CI: -0.35, -0.04) in clustered metabolic risk score (sample mean = 0.06±1.77) with increasing percent of time spent in LPA after adjusting for age, sex, socioeconomic status, smoking, diet, alcohol intake, and medications (55). Similarly, Kim and colleagues reported a significant trend, with decreasing frequency of diagnosed metabolic syndrome across increasing tertiles of LPA in middle-aged Japanese adults (69). Results suggest time spent in LPA is inversely associated with risk of metabolic syndrome, however, more research is needed to draw a conclusion (Table 7).

Cancer

A number of the studies reviewed included participants with cancer, however the current section is limited to examining the association between LPA and risk of cancer diagnosis. Two studies were identified, both case-control designs

examining the relationship of LPA to breast cancer diagnosis. Dallal et al. found a significant trend ($p<0.0001$) in decreased risk for breast cancer diagnosis with increasing quartiles of LPA, while Kobayashi et al. found no significant trend for decreased risk of breast cancer with increasing LPA in older women (30, 73). With conflicting results, more research needs to be done to understand the preventative effect LPA may have on breast cancer risk, in addition to examine the relation of LPA with other cancers (Table 7).

Functional Health

Maximal Oxygen Consumption (VO_{2max}): Two intervention studies included maximal oxygen uptake as an outcome variable. Herzig et al. conducted a 3-month LPA walking intervention in middle-aged adults with results revealing an increase in VO_{2max} in the intervention group (pre 22.7±4.6 ml/kg/min, post 26.3±6.8 ml/kg/min, $p=0.002$) (59). However, there was no significant difference between the intervention and control groups. Ramadi et al. tested exercise capacity using the six-minute walk test on cardiac patients before and after an 8-10 week, low intensity cardiac rehabilitation program in older adults (117). Results showed no statistically significant difference in six-minute walk distance pre and post program (421±98m to 484±85m). These intervention studies suggest LPA may not provide a sufficient stimulus to change VO_{2max}, however this result is to be expected (Table 7).

Physical Function: One study examined the relationship between LPA and physical function. Blair and colleagues examined the effect LPA may have on physical

function (measured by SF-36 function subscale, basic lower extremity function subscale, and advanced lower extremity function subscale) in older cancer survivors (15). Cross-sectional association revealed significant differences in all function scores from the lowest LPA tertile to the highest LPA tertile, however, there were no differences in scores between the highest LPA tertile and the highest MVPA tertile. This suggests high levels of LPA and MVPA elicit similar benefit. Further, when pre-post- data were examined following a 12-month intervention, results indicated a significant increase in the advanced lower extremity function score when high-LPA was increased (12.6 MET-hours/week, IQR: 6.9, 22.0) and MVPA was either decreased or maintained.

Two cross-sectional studies explored the relationship between LPA and mobility. Data from NHANES showed adults with mobility disability accumulate a significantly lower amount of LPA (302.6, 95% CI: 296.7, 308.4) than those who have no disability (363.7, 95% CI: 358.2, 369.3) (95). Laudani et al. looked more closely at the underlying mechanisms affecting mobility across the lifespan (83). While there were significant differences in co-activation, peak torque, and peak power between LPA and more intense activity intensities, further examination revealed differences were likely attributable to declining peak torque, peak power, and increasing coactivation with increasing age, since there were no differences in activity level across age. To date there have been no identified intervention studies that examined change in mobility in response to LPA.

One cross-sectional study examined the effect of LPA on balance parameters. Loprinzi et al. found a significant difference ($p<0.05$) in time spent in LPA between

40-85 year old U.S. adults with a functional balance classification (352.5 min per day) versus those with a dysfunctional balance classification (319.8 min per day) (92). To date there were no identified intervention studies that examined change in balance in response to LPA.

One cross-sectional study explored the relationship between time spent at slow walking speeds and muscle quality, defined as a ratio between lower limb extensor power and lower limb fat free mass (24). Results indicated there was no significant relationship between muscle quality and time spent slow walking speed in healthy older adults. To date there have been no identified intervention studies that examined change in muscle quality in response to LPA.

Arthritis: One case-control study examined 40-80 year old adults with and without Rheumatoid arthritis (RA) (57). Results revealed there were no significant differences in light intensity energy expenditure per day when groups are compared (RA patients: 2198 kcals/day, 95% CI: 2130, 2265; Controls: 2198 kcals/day, 95% CI: 2161, 2234; p=0.242). To date there have been no identified intervention studies that examined change in arthritic symptoms with increasing LPA, therefore, more research is needed to draw a conclusion (Table 7).

Cognition: One cross-sectional study examined the association of cognition and LPA. The Longitudinal Study of Aging from Japan reported a significant trend (p=0.02) in decreasing risk of cognitive decline with increasing quartiles of LPA, with the greatest quartile showing a 69% decrease (95% CI: 0.18, 0.83) in risk of cognitive

decline (87). To date there have been no identified intervention or experimental studies that examined change in cognition in response to LPA, therefore, more research is needed to draw a conclusion (Table 7).

Discussion

Much evidence exists showing the benefits of engaging in MVPA for one's health, and this is reflected in the current public health guidelines. However, to date, little research has explicitly focused on the relationship between LPA and health outcomes. Emerging research is suggesting there may be a benefit to engaging in light intensity physical activities, independent of time spent in MVPA. However, no study has reviewed the current state of the evidence to examine the role LPA may play in benefitting the health of the population. Therefore, the goal of the current systematic review was to discuss the effect LPA may have on 1) all-cause mortality, 2) metabolic health, 3) cardiovascular health, 4) cancer risk, and 5) functional health.

Overall, the results suggest that there was general health benefit to engaging in LPA. Results of this systematic review determined that LPA is beneficially associated with all-cause mortality, glucose, insulin, insulin resistance, c-reactive protein, metabolic syndrome, physical function, and cognition; has no relationship with LDL or total cholesterol; and there is insufficient evidence to support a decision on body mass, BMI, waist circumference, body composition, HbA1c, blood pressure, HDL, triglycerides, cancer risk, VO_{2max}, and arthritis. These associations tended to be stronger in select populations such as older adults or adults with chronic disease.

These groups are largely inactive and are also an important target population for increasing their activity levels. These results suggest this population could greatly benefit from increasing LPA.

An important consideration to keep in mind when reviewing associations between LPA and health variables is that these results cannot be compared head-to-head with MVPA, if energy expenditures are not equated. We cannot discount the potential of LPA as insufficient because there was a change in blood glucose following for example, two minutes of MVPA versus two minutes of LPA. This is a classic example of the dose response between intensity (or energy expenditure) of activity and the benefit to the health indicator (51). For instance, in the experimental study by Dunstan et al., LPA showed a decline in glucose AUC, with MPA showing a greater decline in glucose AUC (35). Both are showing a benefit to glucose handling, and the impact of MVPA greater, which is to be expected. However, the important take home message from these studies should not only be that a minute of MVPA is more beneficial than of a minute of LPA, but that LPA is independently beneficial.

Taking into account the way LPA was measured is an important indicator when examining the strength of the relationship with health variables. Atienza et al. found a stronger relationship between health variables and MVPA when activity was measured using the activity monitor versus a questionnaire (6). These comparisons allow us to evaluate how we have classified activity in the past versus now. Therefore understanding how LPA was measured and the error associated with the methods are important factors to consider.

Questionnaires were used in 21% of the studies reviewed all of which applied cross-sectional study designs. No two studies used the same questionnaire, meaning, out of the 10 studies that utilized questionnaires to measure LPA no questionnaire was repeated. The greatest distinction in questionnaire type is apparent for all-cause mortality. All three all-cause mortality studies (37, 84, 103) were measured using questionnaires, which have been shown to be a weak measure of LPA, as these activities are often hard to identify, recall, and estimate (Ainsworth, 2000). However, Lee et al. used the Harvard Alumni questionnaire, which asks exclusively about leisure time activities (84). When non-exercise activities are added into the questionnaire, as with the Ekblom-Bak et al. and Matthews et al. studies, a relationship is revealed (37, 103). This suggests the more holistic view of our total daily physical activity we can measure, the greater the potential for unveiling the beneficial effect LPA can have on our population.

Overall, 79% of the studies reviewed measured physical activity objectively. However, within the objective measurements there were a number of varying classification schemes used for identifying time spent in LPA. For example, when uniaxial Actigraph accelrometers were used, the upper cutpoint for LPA ranged from 759 cpm to 2020 cpm, almost a threefold difference. An important future consideration is standardizing the classification of LPA. This would aid in the ability to compare the results across these studies. Another important factor that has implications for understanding the relationship between LPA and health outcomes are when LPA is split into two distinct categories. Three recently published studies using NHANES data have differentiated between low light (LLPA) and high light

(HLPA) (39, 61, 94). The majority of the studies have shown a greater relationship between the health variable and HLPA, again providing a dose-response. Regardless of how LPA was measured, the research did still show a positive association between increased time spent in LPA and select health outcomes.

While there were over fifty studies identified for this review, only 16 had a main aim to examine LPA and out of those, 12 were cross-sectional study designs. The majority of the short-term experimental studies were from the sedentary behavior literature and had a LPA component with a focus on breaking up sedentary behaviors. However, while these studies tell us there is a benefit to, for example light walking for two minutes, these chosen stimuli may not be sufficient for understanding the full impact LPA may have on health. Therefore, future studies should focus on the optimal amount of time to spend in LPA, not merely using LPA as a means to break up sedentary behavior. Only one long-term intervention study had a main purpose of examining the effect of a LPA walking intervention over three months. Therefore, there is much more work to be done in understanding the effects of LPA on health variables. In addition, the compliance to and feasibility of LPA programs must be taken into account.

Conclusion

Overall, LPA showed beneficial relationships with all-cause mortality, insulin, insulin resistance, glucose, c-reactive protein, metabolic syndrome, physical function, and cognition, with many other examined categories providing insufficient evidence to conclude the impact of LPA. There are still many gaps in the literature

for future work, however the following directions have been identified as critical to advancing the knowledge base of LPA and health in adults:

- Standardize definitions and classifications of LPA
- Develop accurate and reliable measurements of LPA
- Conduct experimental and intervention studies to confirm or strengthen current results
- Identify key populations LPA would benefit

One consistent finding throughout each health variable examined was the importance of LPA for those who are inactive, which encompasses the majority of our population. Preliminary evidence supports continued research to determine the full benefit of LPA with the potential for addition to future national physical activity guidelines.

Table 7. Evidence for an Association between Light Intensity Physical Activity and Health Outcomes

Variable	
All-Cause Mortality	↑
Metabolic Health	
Body Mass	↑
Body Mass Index	↔
Waist Circumference	↔
Body Composition	↔
Glucose	↑↑
HbA1c	↑
Insulin	↑↑
Insulin Resistance	↑
Cardiovascular Health	
Blood Pressure	↔
High Density Lipoprotein	↔
Low Density Lipoprotein	↓
Triglycerides	↔
Total Cholesterol	↔, ↓
C-reactive Protein	↑
Metabolic Syndrome	↑

Cancer	↔
Functional Health	
VO2max	↓
Physical Function	↔
Arthritis	↔
Cognition	↑

↓: No Relationship
↔: Insufficient evidence to draw a conclusion
↑: Evidence suggesting relationship, but weak
↑↑: Yes, consistent relationship shown

Table 8. Review Study Appendix Table

Supplemental Table.												
Citation	**Study Design**	**LPA Primary Outcome? (Y/N)**	**Inclusion Criteria**	**Exclusion Criteria**	**PA Assessment Tool**	**Acc Analysis (ctpts, wear, etc)**	**Outcome Variables Measured**	**Covariates Measured**	**Final Sample Size**	**Mean Age**	**Statistic/ Model Used**	**Results**
All-Cause Mortality												
Ekblom-Bak E., Ekblom B., Vikstrom M., Faire U., Hellenius M. The importance of non-exercise physical activity for cardiovascular health and longevity. 2013.	Cross-Sectional & Longitudinal	No	Every 3rd man and woman born between July 1, 1937 and June 31, 1938 living in Stockholm County, Sweden. >60 yrs	Excluded 205 individuals with reported MI, heart failure, or stroke and 66 with missign data.	Questionnaire		WC, BP, blood sample - HDL, LDL, TC, TG, insulin, glucose, and fibrinogen. CVD or mortality event.	marital status, education level, smoking habits, regular exercise, dietary intake of vegetables, alcohol intake, self-rated financial status, living conditions, and heredity.	W: 2023, M: 1816		OR (95% CI) for different NEPA levels in relation to being at risk for each dichotomized risk factor. (adj for measured covariates)	Table 2.
											HR (CI 95%) for (A) all cause mortality and (B) CVD event. (adj for measured covariates)	(A) low NEPA 1.00, moderate NEPA 0.86 (0.67-1.08), high NEPA 0.73 (0.53-0.93). (B)

												low NEPA 1.00, moderate NEPA 0.85 (0.69-1.07), high NEPA 0.70 (0.57-0.94).
Lee IM and Paffenbarger RS. Associations of light, moderate, and vigorous intensity physical activity with longevity. 2000.	Longitudinal	No	Harvard Alumni Health Study. Alumni who returned a 1977 questionnaire	Physician diagnosed CVD, cancer, COPD, or did not provide info on PA.	Questionnaire		Mortality	age, cigarette habit, QI, early parental death, diagnosed hypertension or DM	13,485	57.5(8.9)	1) Relative risks of all-cause mortality among Harvard alumni to LPA. 2) Age adjusted mortality rates.	1) No significant trend for kj/wk expended in LPA 2) No significant trend for kj/wk expended in LPA
Matthews CE., Moore SC., Sampson J., Blair A., Xiao Q., Kozey Keadle S., Hollenbeck A., Park Y. Mortality benefits	Cross-Sectional	No	NIH-AARP diet and health study. 50-71 years. Personally responded to both questionnaires, were free of major diseases at the start of		Questionnaire		All cause mortality	age, sex, BMI, education, smoking history, job status, health status, general health, sleep.	154,614	Table 1	Duration of overall PA by type of behavior and sex.	Men: 67% of active time (1.58(1.36) hrs/d) non-exercise. Women: 78% of active time (2.11(1.46) hrs/d).

for replacing sitting time with different physical activities. 2015.			the follow-up, and had sufficiently complete exposure data.								Hazard ratio of all-cause mortality and non-exercise activity by sex. (adjusted for covariates listed.)	(Figure 2B) 1-2 hrs/d of nonexercise activity was associated with 30% reduction in mortality in men and 50-60% reduction in women.
											Isotemporal model (1 hr substitutions) estimated risk (HR 95% CI)for all-cause mortality associated with replacement of 1h of overall sitting with 1h of specific type or intensity of	Less Active: Exercise 0.58 (0.54, 0.63), Non-exercise 0.70 (0.66, 0.74); household chores 0.80(0.74, 0.86), lawn and garden 0.49(0.43, 0.56), daily walking (non-ex)

											PA in less (<2 hrs active) and more active (>2 hrs active) participants	0.66(0.57, 0.78); light 0.81(0.75, 0.88), MVPA 0.58(0.54, 0.62). More active: Exercise 0.91 (0.88, 0.94), Non-exercise 1.00 (0.98, 1.02); household chores 1.02(0.99, 1.05), lawn and garden 0.97(0.93, 1.01), daily walking (non-ex) 0.99(0.94, 1.05); light 1.04(1.01, 1.08), MVPA 0.96(0.94, 0.98)

Metabolic Health												
Assah FK., Brage S., Ekelund U., Wareham NJ. The association of intensity and overall level of physical activity energy expenditure with a marker of insulin resistance. 2008.	Cross-Sectional	No	MRC Ely study. Did not have previously diagnosed diabetes.	No data on fasting insulin or complete free-living heart rate data.	Heart Rate		Fasting Insulin	sex, age, body fat	643	Men 57.9(4.6), Women 57.5(4.0)	Quartiles of time spent above 1.5xRHR (ANOVA - test differences)	No significant change in fasting insulin across quartiles.
											Independent association between "LPA" and insulin resistance (multivariate linear regression). Model 1 adjusted for age, sex. Model 2 adjusted for age, sex, body fat.	No significant independent for "LPA" and insulin resistance.

Bailey DP. & Locke CD. Breaking up prolonged sitting with light-intensity walking improves postprandial glycemia, but breaking up sitting with standing does not.	Randomized, repeated measures cross-over	Yes	free from known metabolic or cardiovascular disease, no contraindications to physical exercise				Glucose, TC, HDL, TG		10	24 (3)	Repeated Measures ANOVA. Glucose AUC by condition	Sig effect of condition (F=8.59, p=0.001, eta2=0.39). Sit + LPA (mean AUC 18.5(17.0, 20.0 mmol/l/5-h) sig lower than sit (22.0(20.5, 23.6) and sit + stand (22.2(20.7, 23.7).
											Repeated Measures ANOVA.BPs, cholesterol values by condition	No significant effect for condition

Banks E., Lim L., Seubsman A., Bain C., Sleigh A. Relationship of obesity to physical activity, domestic activities, and sedentary behaviors: cross-sectional findings from a national cohort of over 70,000 Thai adults. 2011.	Cross-Sectional	No	STOU students across Thailand who had completed at least one semester.	Those without appropriate data…	Questionnaire (Similar to IPAQ and Active Australia Survey.		Obesity (self-reported ht and wt - overweight BMI>23, obese BMI>25)	Age, income, education	74,981	30.2 (7.3)	Relationship between obesity and PA (OR (95% CI)) 0, 1, 2, 3, 4, 5+ sesh/wk (adjusted for age, income, education)	Mild related exercise: 0 sessions/wk reference 1.00. Male: 1.03 (0.94-1.12), 0.90 (0.81-1.00), 0.96 (0.85-1.08), 1.10 (0.94-1.29), 0.87 (0.80-0.94) p-trend 0.004. Female: 0.93 (0.83-1.04), 0.92 (0.81-1.05), 0.78 (0.67-0.91), 0.72 (0.56-0.94), 0.73 (0.64-0.84) p-trend<0.0001.

											Relationship between gardening/ housework and obesity (OR (95% CI)). Seldom or never, 1-3x/month, 1-2x/wk, 3-4x/wk, most days.(adjusted for age, income, education)	Seldom or never reference. Males: 0.83 (0.75-0.93), 0.76 (0.69-0.84), 0.76 (0.68-0.85), 0.67 (0.61-0.74), p-trend<0.0001. Females: 0.94 (0.78-1.13), 0.74 (0.62-0.87), 0.72 (0.60-0.87), 0.67 (0.57-0.79), p-trend <0.0001.

Buman MP., Winkler EAH., Kurka JM., Hekler EB., Baldwin CM., Owen N., Ainsworth BE., Healy GN., Gardiner PA. Reallocating time to sleep, sedentary behaviors, or active behaviors: associations with cardiovascular disease risk biomarkers, NHANES 2005-2006. 2013.	Cross-Sectional	No	NHANES 2005-2006, 20 years and older	Diagnosed sleep disorder or those who were currently pregnant, lactating, or taking insulin. Insufficient valid accelerometry data or those with missing self-reported sleep duration, covariate, or biomarker data.	Accelerometer	Days with 10 or more hours of wear time and 4 or more valid days. SB <100, LPA 100-1951, MVPA >1952. Modification to usual wear time rules - wear period interruptions to any 3 counts less than 50 cts/min and nonwear periods were allowed	WC, HDL, TG, Insulin	sex, race/ethnicity, marital status, education, work status, income, smoking, depressive symptoms, 24-hr dietary recall, general health rating, previous diagnosis of cancer, CVD, diabetes, current use of relevant meds	2185	46.6(18.4)	Population-weight isotemporal substitution regression models reallocated 30-min Sleep or SB to 30-min LPA. RR (95% CI)	TG: Sleep to LPA 0.983 (0.964, 1.002), SB to LPA 0.981 (0.972, 0.991); Insulin: Sleep to LPA 0.998 (0.969, 1.029), SB to LPA 0.976 (0.962, 0.991). HDL, WC non-sig effect of substituting LPA.

						to exceed 12 mindnight.						
Chase JM., Lockhart CK., Ashe MC., Madden KM. Accelerometer-based measures of sedentary behavior and cardio-metabolic risk in active older	Cross-Sectional	No	be able to 65+ yrs. Independently perform all basic ADLs, climb one flight of stairs, and walk 2 blocks without assistance.	Current smokers, known DM, CVD (stroke, transient ischemic attacks, angina, MI, or coronary revascularization) in last 2 years.	Accelerometer	To be included needed 5 valid days. Valid day = 21 hrs/d. Collected 1s epochs. SB <1.5 METs, LPA 1.5-3.0 METs, >3.0 METs = MVPA.	MetS (BP, WC, HDL, FBG, TG), LDL		50	71.5 (0.6)	Pearson correlation for LDL with time in LPA.	r=-0.253 (p=0.071)
											Multivariate regression models for correlates with LDL. Model 1: sit time, LPA time, DBP.	R2 = 0.158.

adults. 2014.												
Chastin SFM., Ferriolli E., Stephens NA., Fearon KCH., Greig C. Relationship between sedentary behaviour, physical activity, muscle quality, and body composition in healthy older adults. 2012.	Cross-Sectional	No	Healthy, older adults		Accelerometer	Inclinometer used to identify SB and lying from standing/stepping. Time spent walking broken into low (<93 steps/min, <3 METs), moderate, vigorous (>124 steps/min, >6 METs).	% body fat, lower limb body fat, LLEP, MQ, and fragmentation F (ratio of the # of sedentary bouts/total sedentary time).		30	Men: 79.0 (3.6), Women: 79.3 (3.4)	Generalized linear model predicting muscle quality. Fragmentation (F) + low walking.	Females: no sig effect. Adjusted R2=0.261 variance in MQ explained by F+low walking. Males: no sig effect, R2=0.273.

Dunstan DW et al. Breaking up prolonged sitting reduces postprandial glucose and insulin response. 2012.	randomized, three-period, three-treatment crossover trial	No	45-65y, BMI >25	pregnancy, clinically diagnosed diabetes, taking glucose or lipid lowering meds, employment in non-sed occupation, watch <2 hr tv/d, >150min/wk PA for 3 mo, contraindications to being PA.			Glucose, insulin	age, sex, weight, period effects, and predrink levels	19	53.8(4.9)	Generalized estimating equations (adjusting for age, sex, weight, period effects, and predrink levels). Glucose response.	5-h iAUC sit + LPA 5.2(4.1, 6.6) mmol/l, sit + MPA 4.9(3.8, 6.1) mmol/l, significantly lower (p<0.01) than the sit condition (6.9(5.5, 8.7) mmol/l). No sig condition effect for 2-h plasma glucose.
											Generalized estimating equations (adjusting for age, sex, weight, period effects, and predrink levels).	5-h iAUC sit + LPA 633.6(552.4, 727.1) mmol/l, sit + MPA 637.6(555.5, 727.1) mmol/l, significantly lower (p<0.001)

											insulin response.	than the sit condition (828.6(722.0, 950.9) mmol/l). No sig condition effect for 2-h serum insulin.
Duvivier BMFM., Schaper NC., Bremers MA., van Crombrugge G., Menheere PPCA., Kars M., Savelberg HHCM. Minimal intensity physical activity (standing and walking) of longer duration improves insulin action and	counterbalanced, randomized, crossover design	No	PA less than 1 hr/wk, between 20-30 BMI, aged 18-30y	any drug use, diseases that interfered with PA, frequent alcohol use, fasting TG >3 mmol/l, and fasting glucose >6.0 mmol/l.	Accelerometer/Inclinometer		fasting glucose, TC, TG, HDL, LDL		18	21 (2)	Repeated Measures ANOVA	TG (mmol/l): sig sit(0.90(0.26)) to MIPA (0.70(0.23)), and exerc (0.85(0.35)) to MIPA. AUC insulin: sig sit (7752.0(3015.4)) to MIPA (6727.3(4329.4), and exerc (8320.4(5383.7)) to MIPA.

plasma lipids more than shorter periods of moderate to vigorous exercise (cycling) in sedentary subjects when energy expenditure is comparable. 2013.												
Falconer CL., Page AS., Andrews RC., Cooper AR. The potential impact of displacing sedentary time in adults	Cross-Sectional	No	Early Activity in Diabetes (Early Actid) - a randomized controlled trial of PA and diet in early management of T2DM. Been	Uncontrolled diabetes, blood pressure, BMI <25, body weight >180 kg.	Accelerometer	Nonwear time >60 min consecutive zeros. Days with at least 10 hours of wear time used.	BMI, WC, HbA1c, HDL, LDL, TG, glucose, HOMA-IR.	sex, age, ethinicity, IMD score, BMI, wear time, relevant drugs.	519	59.9(9.9)	Linear regression (association) between each 30-min of LPA with cardiometabolic biomarkers. (adjusted for reporte covariates)	BMI -0.41 (-0.61, -0.22), -1.15 (-1.15, -0.70); HbA1c, HDL, LDL, TG, FPG, HOMA-IR non-sig.

with type 2 diabetes. 2015.			diagnosed with T2DM within the past 6 months and were age 30-80 years at diagnosis.			MVPA >1952, SB <100, LPA 101-1951. Long bout SB sed time in bouts of 30 min+, short bouts sedentary time >30 min.					Estimated impact of reallocating 30-min/d of SB bouts (1) or SB non-bouts (2) with LPA.	BMI (1) -0.26 (-0.47, -0.05), (2) -0.01 (-0.38, 0.36); WC (1) -0.87 (-1.35, -0.39), (2) -0.44 (-1.3, 0.41); HDL non-sig.
Gando Y., Murakami H., Kawakami R., Tanaka N., Sanada K., Tabata I., Higuchi M., Miyachi M. Light-intensity physical activity is associated with insulin resistance in elderly	Cross-Sectional	Yes		Smoking, receiving medication for hypertension, hyperlipidemia, or diabetes. History of stroke, cardiac disease, or chronic renal failure. Taking oral contracep	Accelerometer	Needed at least 14 days wear to be included in analysis. Equation to analyze acceleration on page 267 of paper.	HOMA-R	age, sex, wc, VO2peak, MVPA	807	Women young 42 (6), elderly 59 (5). Men	Regression analysis of LPA with HOMA-R (Model 2 adjusted for age, sex, wc, and MVPA	LPA beta= -0.125 (-0.001, -0.0002) p<0.001. R2=0.243. (MVPA beta = -0.132, R2=0.243)
											Marginal means of HOMA-R stratified by quartiles of LPA in subgroups. Adjusted	Elderly p trend = 0.001, Women p trend = 0.001, unfit p trend = 0.004.

Japanese women independent to moderate-to vigorous-intensity physical activity. 2014.				tives, or HRT. Excluded if regularly swim, cycle, or weight train.						young 39 (6), elderly 58 (5)	for age, sex, wc, VO2peak, and MVPA.	
Gay JL., Kohl HW., Salinas JJ., McCormick JB., Fisher-Hoch, SP. Contribution of occupation to high doses of light-intensity activity and cardiovascular risk factors among Mexican American	Cross-Sectional	Yes	Cameron County Hispanic Cohort. 18 years of age or older and willing to wear an accelerometer.	Unemployed or did not meet wear time criteria.	Actigraph GT1M, hip-worn	Minimum of 10 hours on at least 3 days (2 week days and 1 weekend). Freedson cutpoints.	BP, WC, fasting BG, HDL, TG, BMI, BF%		118	48.2 (13)	Pearson's Correlation Coefficients for LPA and CV RF (* p=0.025)	SBP -0.12, DBP -0.09, WC -0.04, BG 0.09, HDL -0.04, TG -0.07, BMI -0.01, BF% -0.06.

adults. 2014.												
Green AN, McGrath R, Martinez V, Taylor K, Paul DR, Vella CA. Associations of objectively measured sedentary behavior, light activity, and markers of cardiometabolic health in young women. 2014.	Cross-Sectional	Yes	20-39 years, regular menstrual cycles, premenopausal, testing during follicular stage of cycle.	Diagnosed CV, metabolic, or systemic disease, currently using antihypertensive or lipid lowering meds, pregnant or breast feeding, irregular menstrual cycles, currently smoking or smoked in last 6 months, or unable	Actigraph GT3X+	SB <150, LPA 150-2689, MVPA >2689. Non-wear >60 min consecutive 0s. 4 valid days (>10 hrs)	WC, glucose, BP, TG, TC, HDL, LDL, lipid accumulation product, HOMA-IR, Insuin, CRP, IL-6, TNF-α, adiponectin, VO2peak, wt, body comp	MVPA, body comp, body mass, VO2peak	50	24.0 (4.8)	Correlations between LPA and IV (*sig)	TG -0.44*, TC -0.29*, LAP -0.35*, HOMA-IR -0.29*

				to perform exercise test.								
Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, Owen N. Objectively measured light-intensity physical activity is independe	Cross-Sectional	Yes	Participants in the AusDiab study	Known diabetes, visible limitations to mobility, and pregnant women.	Actigraph 7164	SB <100, MVPA >1952. Included if had 5 valid days (1 wknd): 10 hours.	Fasting Plasma Glucose, 2h Plasma Glucose	age, sex, wear time, height, wc, accelerometer unit number, alcohol intake, education, income, smoking status, family	173	53.3 (51.5-55.1)	Regression Analysis: Model 1 (age, sex, wear time)	LPA and 2h PG: b= -0.30 (p=0.002)
											Model 2 (+ ht and wc, acc unit number, alcohol intake, education, income, smoking status, fam history of diabetes)	LPA and 2h PG: b= -0.25 (p=0.012)

ntly associated with 2-h plasma glucose. 2007.								history of diabetes			Model 3 (+ MVPA)	LPA and 2h PG: b= -0.22 (p=0.023)
											Trends in decreasing 2h PG with increasing quartiles of LPA	p=0.006 for trend in LPA quartile and 2hr PG. Men q: 19.26% of waking hrs, 22.65, 26.27; women q: 20.19, 24.47, 27.54%.
Healy GN., Wijndaele K., Dunstan DW., Shaw JE., Salmon J., Zimmet PZ., Owen N. Objectively measured sedentary time, physical activity, and	Cross-Sectional	No	Subset of The Australian Diabetes, Obesity, and Lifestyle Study AusDiab) Aged 30-87 y	Diagnosed diabetes	Accelerometer	SB <100, MVPA >1952, mean intensity of activity duration (total accelerometer counts per total monitoring time)	WC, TG, HDL, BP, FPG, clustered metabolic risk score.	age, sex, employment status, alcohol intake, income, education, smoking status, diet quality, and family history of	169	53.4	Standardized regression coefficients of percent of time spent in LPA and metabolic risk variables (adjusted for age, sex, employment status, alcohol	WC -0.20 (-0.34, -0.06), Clustered metabolic risk -0.20 (-0.35, -0.04).

metabolic risk. 2008.								diabetes, lipid lowering meds.			intake, income, education, smoking status, diet quality, and family history of diabetes). Met risk: additionally adjusted for lipid lowering meds.	
Healy GN, Winkler EAH, Brakenridge CL, Reeves MM, Eakin EG. Accelerometer-derived sedentary	Cross-Sectional	No	Diagnosed T2DM, aged 20-75 years old, BMI overweight or obese, and inactive (<guidelines).		Actigraph GT1M	SB <100, MVPA >1952. Valid day: >10 hours and no min with count >20,000.	Weight, Height, WC, HbA1c, plasma glucose, HDL, TG	Demographics, diet, smoking status, use of weight loss aids, chronic physical and	279	58.2 (8.6)	Cross-sectional associations of each 30 min/day of LPA (Model 1: wear time and confounders)	WC (cm) β= -0.61 (-1.14, -0.09), BMI β= -0.29 (-0.52, -0.05), FPG (mM) RR=0.98 (0.97, 1.00)

and physical activity time in overweight/obese adults with Type 2 Diabetes: cross-sectional associations with cardiometabolic biomarkers. 2015.								psychological conditions, diabetes history and management, current meds.			Cross-sectional associations with substituting 30 min of prolonged sitting with 30 min of LPA (Model 3: confounders, wear time, time in each activity)	WC (cm) β= -0.77 (-1.33, -0.22), BMI β= -0.36 (-0.61, -0.11)
Herzig KH., Ahola R., Leppaluoto J., Jokelainen J., Jamsa T., Jeinanen-Kiukaanniemi S. Light physical activity determined by a motion sensor decreases	Randomized controlled trial	Yes	PreDiabEx. Impaired fasting glucose or impaired glucose tolerance.	Any functional limitations, chronic disease, any meds for diabetes, or current VPA >75 min/wk.	Accelerometer		Fasting and 2h glucose and insulin, vo2max, daily steps, lipids, body weight, and fat distribution	diet	Exercise 33, Control 35	Ex 58.1(9.9), Con 59.5(10.8)	2-h insulin and LDL pre-post between groups. All other outcomes non-significant.	2h insulin: Ex Pre 116.9(70.8), Post 75.6(62.7), Con Pre 94.8(72.8), Post 91.4(60.6), Diff 26.6(1.1-51.8). LDL (mmol/l): Ex 3.0(0.8), 3.0(0.8), Con 3.2(1.2),

insulin resistance, improves lipid homestasis and reduces visceral fat in high-risk subjects. 2014.												3.6(1.0), Diff 0.4(0.1-0.7)
Howard B, Winkler EAH, Sethi P, Carson V, Ridgers N, Salmon J, Healy GN, Owen N, Dunstan D. Associations of low- and high-intensity light activity with cardiometabolic biomarkers. 2015.	Cross-Sectional	Yes	2003/4 and 2005/6 NHANES	Pregnancy, taking insulin, and not having accelerometer data	Actigraph 7164	SB <100, LLPA 100-759, HLPA 760-1951, MVPA 1952-5724, VPA >5724. Wear time >60 min consecutive 0s. Four valid days (>10 hrs)	WC, resting BP, non-fasting HDL and CRP, fasting TG, PG, and insulin, 2h PG	Race/ethnicity, education, marital status, family poverty income ratio, smoking status, diet, medical history, current meds	4614	46.8 (17)	Associations per standard deviation (LLPA SD=62.5 min; HLPA SD= 44.8 min) with biomarkers. Model A: adjusted for sociodemo, behavioural, and med covariates retained through backward elimination. Reported as IV (βLLPA,	WC (-0.92*, -1.14*), BMI (-0.24, -0.28*), SBP (1.00*, 0.99), CRP (0.92*, 0.86*), HDL (1.01, 1.02*), TG (0.96*, 0.96*), PG (1.00, 0.99*), Insulin (0.93*, 0.87*), HOMA %B (0.94*, 0.96*), HOMA %S

											βHLPA) *=sig	(1.07*, 1.07*)
											Associations per standard deviation (LLPA SD=62.5 min; HLPA SD= 44.8 min) with biomarkers. Model B: Model A + WC. Reported as IV (βLLPA, βHLPA) *=sig	SBP (1.01*, 1.00), CRP (0.95*, 0.90*), HDL (1.01, 1.01*), TG (0.97*, 0.97*), Insulin (0.95*, 0.91*), HOMA %B (0.96*, 0.97*), HOMA %S (1.05*, 1.06*)
Kwon S., Mohammad J., Samuel I. Physical activity patterns in	Cross-Sectional	No	New Pre-bariatric surgery patients.		Accelerometer	Wear time >22 hrs/day needed for analysis.	Morbid obesity (MO) and normal weight women		MO: 18, Normal: 7	MO: 42, Norm	Correlations of BMI with locomotion parameters. *=p<0.05	Standing time r=-0.53*, Walking time r=-0.54*, Walking

morbidly obese and normal-weight women. 2011.										al: 44.4		step count r=-0.61.
Larsen, RN., Kingwell BW., Robinson C., Hammond L., Cerin E., Shaw JE., Healy GN., Hamilton MT., Owen N., Dunstan DW. Breaking up of prolonged sitting over three days sustains, but does not enhance, lowering of postprandial glucose and	randomized crossover trial	No	Sedentary, BMI 25-45, aged 45-75y, non-diabetic, non-smoking, not taking glucose or lipid lowering meds, or antucoagulant. Not meeting PA guidelines.				fasting glucose, 2h glucose, glucose tAUC, insulin tAUC, fasting TG, TG tAUC, HOMA	age, gender, BMI	19	56.7(1.5)	Generalized estimating equations (adjusted for age, gender, BMI)	Sig condition effect for 2h glucose, glucose tAUC, insulin tAUC. Sig time effect for fasting glucose, fasting TG, TG tAUC, HOMA.

insulin in overweight and obese adults. 2014.												
Littman AJ., Kristal AR., White E. Effects of physical activity intensity, frequency, and activity type on 10-y weight change in middle-aged men and women. 2005.	Retrospective cohort study	No	VITamins, And Lifestyle (VITAL) study. Between 53-57 at baseline.	History of diseases that may lead to weight loss or poor self-reported health. Missing or out of range values for height, weight, or BMI, those who did not complete the questions on PA.	Questionnaire		Weight change (lbs)	baseline age, weight at age 45, change in weight from 30 to 45, education, smoking, energy from all macronutrients.	15,500	53-57	Linear regression coefficients (95% CI) for mean weight chang ein pounds from 45 y with Low intensity PA (1) per 5-MET-hr week, (2) per session/week. Stratified by BMI (<25, 25-30, >30) and sex. (adjusted for reported covariates)	(1) women: -0.42 (-0.7, -0.1), -1.74 (-2.5, -0.7), -1.94 (-3.9, -0.02). Men: -0.15(-0.4, 0.1), -0.23 (-0.6, 0.1), -0.18 (-1.3, 0.9). (2) Women -0.35 (-0.5, -0.2), -0.84 (-1.4, -0.3), -1.62 (-2.7, -0.5). Men: -0.17 (-0.4, 0.02), -0.31 (-0.6, -0.1), -

												0.74 (-1.6, 0.1).
Loprinzi PD., Lee H., Cardinal BJ. Objectively measured physical activity among US cancer survivors: considerations by weight status. 2013.	Cross-sectional	No	Had been diagnosed with breast, colon, prostate, or endometrium cancer	Diagnosed with cancer within the last 5 years, missing data on weight variables, or any covariates	Actigraph 7164	SB <100, MPA >2020, VPA >5999. (VPA mins were multiplied by 2 since Vig is 2x Mod METs.) Wear time >60 min consecutive 0s. Four valid days	BMI (normal <25, overweight 25-29, obese >30.	Age, gender, race-ethnicity, poverty-income ratio, diagnosed CHD, stroke, arthritis	126	68.3 (1.1)	Min/day LPA by group (mean (SE))	Breast 296 (11.7), Colon 313.9 (22.3), Prostate 276.9 (13.4), Uterus 304.9 (24.5), All 294.8 (8.2). Normal 302 (17.4), Overweight 301.8 (11.6), Obese 281.9 (17.2)

						(>10 hrs)					Association between weight status and PA LPA coefficient (95% CI) Rate ratios from negative binomial models (rate of event while all other variables held constant) Covariates include age, gender, race, PIR, CHD, stroke, arthritis, wear time	Normal (referent), Overweight (6.9 (-32.9, 46.8)), Obese (-19.4 (-65.2, 26.3)); age (-2.5 (-3.7, -1.3); Non-white (10.6 (-30.4, 51.8)) white (referent); Male (referent), female (0.1 (-13.7, 14))
Loprinzi PD., Sheffield J., Tyo BM., Fittipaldi-Wert J.	Cross-sectional	No	NHANES 03-06		Actigraph 7164	SB <100, MPA >2020, VPA >5999. Wear	Mobility Limitation, BMI, WC, CRP, HDL, TG, fasting glucose,	Age, gender, race-ethnicity, poverty-	No disability n=3872, disabi	ND: 42.1 (41.	Mean min/day spent in LPA	ND: 363.7 (358.2, 369.3), D: 302.6 (296.7, 308.4)

Accelerometer-determined physical activity, mobility disability, and health. 2014.						time >60 min consecutive 0s. Four valid days (>10 hrs)	white blood cells, neutrophils, hemocysteine, HbA1c	income ratio, BMI, cotinine, comorbidity index, and wear time	lity n=1703	2, 42.9), D: 60.6 (59.3, 61.8)	Association between LPA and bio markers (linear regression model; age, gender, race, BMI, cotinine, comorbidity index, PIR, wear time, MVPA)	BMI -0.01 (-0.01, -0.004), WC -0.01 (-0.02, -0.009)
Loprinzi PD., Lee H., Cardinal BJ. Evidence to support including lifestyle light-intensity recommendations in physical activity guidelines for older adults. 2014.	Cross-sectional	Yes	NHANES 03-06. 65 y or older.	Insufficient accelerometry data.	Actigraph 7164	Lifestyle LPA 760-2020. MVPA >2020. Wear time >60 min consecutive 0s. Four valid days (>10 hrs).	BMI, WC, tricep and subscap skinfold, BP, CRP, HDL, LDL, TC, TG, FG, insulin, cotinine, homocysteine, HbA1c, HOMA	Age, gender, race-ethnicity, poverty-income ratio, number of comorbidities, functional disabilities, wear time.	No comorbidities: n=102, 1+ comorbidity: n=1394	None: 71.6 y, 1+: 74.0 y	Weighted mean of health variables across activity status. >300 min/wk of LPA, <300 min/wk of LPA (all reported sig)	BMI 27.5, 28.5*, SBP 134.2, 139.2, WC (cm) 98.8, 101.2, tricep skinfold (mm) 18.6, 20.2, CRP (mg/dL) 0.32, 0.51, white blood cell (1000 cells/microL) 6.91, 7.49, neutrophil

												s (1000 cells/microL) 4.05, 4.45, Glucose (mg/dL) 107.3, 113.5, Insulin (microU/L) 9.6, 12.3, HOMA 2.7, 3.7, HbA1c (%) 5.65, 5.88.
											Multivariable Poisson regression. Activity status (LPA >300 min/wk, <300 min/wk) and comorbidity index (count variable) (Adjusted computed with both LPA and MVPA in model)	Unadjusted Incident rate ratio (95% CI) = 1.35 (1.23, 1.47). Adjusted IRR = 1.18 (1.09, 1.27)

Lyden K., Keadle SK., Staudenmayer J., Braun B., Freedson PS. Discrete features of sedentary behavior impact cardiometabolic risk factors. 2015.	Experimental	No	Good physical health (no diagnosed cardiovascular, pulmonary, metabolic, joint, or chronic disease). Currently participating in 150 min of moderate PA/wk.		Accelerometer		Lipids, fasting and 2-h glucose and insulin, AUC glucose and insulin, ISI	diet	10	25.2(5.7)	Linear regression. Association between change in LPA and 2h plasma.	Beta=-4.89, r=-0.62, p=0.05. No sig effect on other variables.
Lynch BM., Dunstan DW., Healy GN., Winkler E., Eakin E., Owen N. Objectively measure physical activity and sedentary time of breast cancer survivors, and associations with	Cross-Sectional	No	NHANES 03-06. Women who self reported having had breast cancer.	Told by a doctor they had diabetes or missing outcome data.	Accelerometer	SB <100, LPA 100-1951, MVPA >1952. Valid day >10 hrs. Wear time at least 60 consecutive zeros. Skewness in MVPA and outcome	Waist Circumference & BMI (in breast cancer survivors), serum insulin in subsample	age, ethnicity, education, marital status, total energy intake. (ethnicity and marital status removed bc not sig), MVPA or SB.	BCS n=111, controls n=3830	BCS 69.2 (13.0), controls 48.5 (18.7)	Associations (Linear Regression) of LPA (h/d) with WC (cm) and BMI (kg/m2) among BCS. (model 2 adjusted for age, education, energy intake; model 3 additionally adjusted for MVPA)	WC (2,3): -4.362 (-7.727, -0.996), -2.512 (-5.778, 0.753); BMI (2,3): -0.977 (-2.140, 0.186), -0.327 (-1.545, 0.891); log serum insulin (2,3): -0.261 (-0.483, -0.069), -

adiposity: findings from NHANES (2003-2006). 2009.						data with MVPA were corrected using natural log transform.						0.187 (-0.427, -0.052)
Lynch BM., Dunstan DW., Winkler E., Healy GN., Eakin E., Owen N. Objectively assessed physical activity, sedentary time and waist circumference among prostate cancer survivors: findings from the NHANES (2003-	Cross-Sectional	No	NHANES 03-06. Men who have been told by a doctor they have or have had prostate cancer.	Missing waist circumference measurement.	Accelerometer	SB <100, LPA 100-1951, MVPA >1952. Valid day >10 hrs. Wear time at least 60 consecutive zeros. Skewness in MVPA and LPA was corrected using natural log	Waist Circumference (in Prostate cancer survivors)	age, ethnicity, education, marital status, total energy intake. (ethnicity and marital status removed bc not sig), MVPA or SB.	103	75.4(7.3) y	Associations (Linear Regression) of LPA (h/d) with waist circumference (model 2 adjusted for age, education, energy intake; model 3 additionally adjusted for MVPA).	Model 2: Regression coefficient =-8.371 (-18.964, 2.222) p=0.114, Model 3: Regression coefficient =-3.940 (-14.272, 6.392) p=0.432.

2006). 2010.						transform.						
Maher C, Olds T, Mire E, Katzmarzyk P. Reconsidering the sedentary behavior paradigm. 2014.	Cross-Sectional	No	>20 years, participated in NHANES 2005/6	Pregnant women, those taking insulin, or those missing variables of interest	Actigraph 7164	SB <100, MVPA >2020. Wear time >60 min consecutive 0s. Four valid days (>10 hrs)	WC, resting BP, non-fasting HDL and CRP, fasting TG, PG, and insulin, 2h PG	age, sex, ethnicity, income, education, medical and family history, smoking status, dietary recall, daily alcohol intake	4618		Linear Regression (Model 6: SB hrs, wear time, sociodemographic, medical history, behaviour, TAC)	IV (β, adjusted R^2, *=sig): WC (-0.37, 0.264), LOG SBP (-0.004, 0.224), DBP (0.13, 0.137), LOG HDL (0.003, 0.258), LOG CRP (-0.06*, 0.119), LOG TG (0.04*, 0.135), LOG PG (-0.003, 0.359), LOG insulin

												(0.02, 0.208), LOG HOMA %B (0.02, 0.173), LOG HOMA %S (-0.02, 0.214), LOG OGTT (0.01, 0.204)
Manohar C., Levine JA., Nandy DK., Saad A., Man CD., McCrady-Spitzer SK., Basu R., Cobelli C., Carter RE., Basu A., Kudva YC. The effect of walking on postprandial glycemic excursion in patients with type 1 diabetes and	prospective	No	part of a larger study		Accelerometer/Inclinometer		glucose		12, 12	healthy: 37.7(13.7), T1D: 37.4(14.2)	randomized complete block ANOVA for glucose iAUC.	controls: post meal walking: 4.5(0.9, 8.0) mmol/l, post meal inactivity: 9.6(6.0, 13.2). Type 1 diabetes: post meal walking: 7.5(3.9, 11.0) mmol/l, post meal inactivity: 18.4(14.8, 22.0) mmol/l.

healthy people. 2012.												
Riou ME., Abdulnour J., Brochu M., Prud'homme D., Rabasa-Lhoret R., Doucet E. Light physical activity is a better determinant of lower adiposity during the menopausal transition. 2014.	Prospective observational	No	Premenopausal women between 48 and 55, regular menstrual cycles, non-smoker, BMI 20-29, reported weight stability, no known disease or disability, no current meds influence energy intake or metabolism.	Taking HRT.	Accelerometer		Weight, BMI, WC, fat mass, fat free mass, % body fat, central fat mass, peripheral fat mass, maximal aerobic power	Time spent in other activity intensities	65	49.7(1.8)	Correlations between LPA and Ivs (*p<0.05)	Fat mass: yr 1 -0.38*, yr 5 -0.29*, BF% yr 1 -0.42*, yr 5 -0.31*, Central fat mass: yr 1 -0.36*, yr 5 -0.26*. Peripheral fat mass yr 1 -0.33*, yr 5 -0.27*.
											Tertiles of LPA and Ivs at yr 1.	Low light (LL) 1451(170) min/wk, moderate light (ML) 1744(73) min/wk, High light (HL) 2081(179). Fat mass: LL

												20.7(4) kg, ML 20.3, HL 16.6, p-trend - 0.03. BF% LL 34.5(5.1), ML 32.2(7.7), 28.1(6.2), p-trend=0.02. Central fat mass LL 10.1(2.6), ML 10(3.8), HL 7.8(2.4), p-trend = 0.04.
Smith HA., Storti KL., Arena VC., Kriska AM., Gabriel KKP., Sutton-Tyrell K., Hames KC., Conroy MB.	Cross-Sectional	No	Moderately overweight or obese (25-39.9) men and women, 20-45 years of age from Allegheny county, PA. Not being regularly active (<3	Had diabetes, treated for hypertension or an average screening BP >140/90, were on cholesterol	Accelerometer	Wear time 60 consecutive zeros, needed minimum of 10 hrs/wear/d. SB <100, Light 100-	Visceral Adipose Tissue (VAT), Total abdominal adipose tissue, Intramuscular adipose tissue, total thigh	Wear time, age, race, education, BMI	253	38.1(5.8)	Multivariate regressions models assessing LPA relationship with total abdominal adipose tissue. Standardized	M: -0.19, p=0.02, Adj R2=0.71. F 0.004 p=0.93, adj R2 = 0.68.

Association between accelerometer-derived physical activity and regional adiposity in young men and women. 2013.			hrs/wk in 8 of last 12 months).	lowering, antipsychotic, or vasoactive meds, pregnant or breast feeding.		1951, MPA 1952-5724, VPA >5825	adipose tissue.				regression coefficient, Adj R2. (adjusted for wear, age, race, education, and BMI)	
											Multivariate regressions models assessing LPA relationship with VAT. Standardized regression coefficient, Adj R2. (adjusted for wear, age, race, education, and BMI)	M: -0.30, p=0.03, adj R2=0.15. F: -0.09, p=0.14, Adj R2=0.47.

Swartz AM., Tarima S., Miller NE., Hart TL., Grimm EK., Rote AE., Strath SJ. Prediction of body fat in older adults by time spent in sedentary behavior. 2012.	Cross-Sectional	No	50-90 years	Use of a cane or other assistive device, CVD, pulmonary disease, peripheral vascular disease, type 1 or 2 DM, high blood pressure, or orthopedic limitations that would affect walking.	Accelerometer	LPA 100-759 cts/min, Wear time >60 minutes of consecutive zeros, 600 minutes for a valid day, 4 valid days (including 1 weekend) for analysis.	Total Body Fat %, Abdominal fat %, BMI, WC	gender, age	232	64.3(6.9)	Pearson Product-Moment Correlation time spent in LPA and body size/fat (corrected for wear time)	BMI -0.258 (P<0.001), WC -0.292 (p<0.001). Age, body fat %, abdominal fat % non-sig.

Yates T., Henson J., Edwardson C., Dunstan D., Bodicoat DH., Khunti K., Davies MJ. Objectively measured sedentary time and associations with insulin sensitivity: Importance of reallocating sedentary time to physical activity. 2015.	Cross-Sectional	Yes	Walking Away from Type 2 Diabetes study. Adults at an increased risk of type 2 diabetes (90th %ile of Leicester Risk Score.	Previously diagnosed with type 2 diabetes, were currently taking steroids, or were unable to take part in any walking activity.	Accelerometer	Sedentary (<25 cts/15s), light (25-488 cts/15s), MVPA >488 cts/15s). Non wear 60 min of continuous zeros, at least 600 min wear time and 4 days.	Glucose regulation and insulin sensitivity	age, sex, ethnicity, social deprivation, smoking status, beta blocker and statin med status, BMI.	508	65 (60-69 IQR)	Association of substituting 30 min of sedentary behavior for LPA with measures of insulin sensitivity and glucose regulation using isotemporal substitution. (Model 1 adjusted for ethnicity, sex, smoking status, age, beta blocker and statin meds, IMD score. Model 2 adjusted for model 1 + BMI)	2-h glucose (1) 0.97(0.95, 0.99), (2) 0.97(0.95, 0.99); 2-h insulin (1) 0.96(0.92, 1.00), (2) 0.96(0.91, 1.00); Matsuda-ISI (1) 1.05(1.01, 1.09), (2) 1.04(1.00, 1.08). Non-sig association in fasting glucose and insulin and HOMA-IS.

											Association of substituting 30 min of sedentary behavior for LPA stratified by IGR status. Normal glucose metabolism vs IGR.	No association in normal glucose individuals. HOMA IS 1.07(1.02, 1.12), Matsuda-IS 1.09(1.15).
Cardiovascular Health												
Duncan MJ., Birch SL., Oxford SW. The effect of exercise intensity on postresistance exercise hypotension in trained men. 2014.	Randomized crossover design	Yes	19-36y, male, regular exercisers.	Smokers, high resting BP, used meds that influence CV response or substances that could affect performance, or any muscle, bone, or joint injury.			SBP, DBP, MAP, HR	Resting BP and HR	16	23.1(5.9)	Repeated measures ANOVA (intensity and time).	Significant intensity x time interaction for SBP. Significantly lower SBP after high intensity exercise compared to low intensity (p=0.01). No main effect for DBP. MAP was significantly lower at

												50 and 60 min recovery for high intensity compared to low-intensity (p=0.05).
Hamer M., Stamatakis E., Steptoe A. Effects of substituting sedentary time with physical on metabolic risk. 2014.	Cross-Sectional	Yes	Whitehall II epi cohort. No history or objective signs of CHD and no previous diagnosis or treatment for hypertension, inflammatory diseases, or allergies. Aged 59-79 y.	Did not meet accelerometer wear time.	Accelerometer	Needed 4-7 valid days of 10 hrs/d. Nonwear = 60 consecutive zeros. Cutpoints: SB 0-199, LPA 200-1998, MVPA >1999.	HbA1c, HDL, BMI, TG	smoking level, statin use, SES	445	66 (6) y	Linear Regression single-factor models. Reported B, all non-significant. Adjusted for wear time, age, sex, smoking, employment, statin use.	HbA1c 0.001, BMI -0.02, HDL 0.006, TG -0.005
											Isotemporal substitution replacing 10min in SB with 10min of LPA. B (95% CI)	HbA1c 0.001 (0.006, -0.009), BMI -0.002 (-00.059, 0.056), HDL 0.005 (-0.001, 0.01), TG -

												0.004 (-0.014, 0.006).
Kim J., Tanabe K., Yokoyama N., Zempo H., Kuno S. Objectively measure light-intensity lifestyle activity and sedentary time are independently associated with metabolic syndrome: a cross-sectional study of Japanese adults. 2011.	Cross-Sectional	Yes	Healthy, middle aged, Japanese adults, without diabetes, cardiovascular disease, or musculoskeletal diseases.	missing data on PA, MetS components, or dietary intake.	Accelerometer	Valid day 600 min, for 7 days.	MetS, abdominal obesity, hypertension, hyperglycemia, dyslipidemia, WC, BP, FG, TG, HDL	age, sex, smoking status, calorie intake, wear time, MVPA	483	47.9(9.0)	Frequency of MetS and its components according to tertiles of LPA in daily life. (<11.1 MET-hr/d, 11,2-14.5, >14.6)	Significant decreasing trend across tertiles for MetS, abdominal obesity, dyslipidemia.
											Multivariable associations between LPA and MetS components. Adjusted for age, sex, smoking status, calorie intake, wear time, MVPA	WC (cm) -0.827(-1.518, -0.137), HDL (mg/dL) 1.118 (0.188, 2.049), zMetS -0.249 (-0.448, -0.051)

											Associations between LPA and prevalence of MetS and its components. OR across tertiles (<11.1 MET-hr/d, 11,2-14.5, >14.6).	MetS 1(R), 1.51(0.29, 0.89), 0.44(0.24, 0.81) p=0.012; Abdominal obesity 1(R), 0.46(0.28, 0.76), 0.50(0.30, 0.84), p=0.005; Dyslipidemia 1 (REF), 0.68(0.39, 1.17), 0.39(0.20, 0.74) p=0.016.
Larsen RN., Kingwell BA., Sethi P., Cerin E., Owen N., Dunstan DW. Breaking up prolonged sitting reduces resting	Randomized crossover design	No	Non-smokers, aged 45-65y, with a BMI 25-45 kg/m2.	taking glucose or lipid-lowering meds or met current PAG.			Blood Pressure	age, sex, BMI, fasting BP, and treatment order	19	53.8(1.1)	Generalized estimating equations (adjusted for age, sex, BMI).	Significant differences in treatment, LPA and MPA breaks reducing SBP to similar extent (LPA 120(1) mmHg,

blood pressure in overweight/obese adults. 2014.												p=0.002) (MPA 121(1) mmHg, p=0.02) compared to uninterrupted (123(1)mmHg) and DBP (LPA 76(1) mmHg, p=0.006), (MPA 77(1) mmHg, p=0.03) compared to uninterrupted sitting (79(1) mmHg).
											Sensitivity analysis. Hypertension group only.	Significant effect for only LPA condition for SBP (129(2) mmHg) and DBP (8.4(1) mmHg)

												compared to uninterrupted sitting (SBP: 133(2) mmHg, p=0.009; DBP: 87(1) mmHg, p=0.002).
Laursen ASD., Hansen ALS., Wiinberg N., Brage S., Sandbaek A., Lauritzen T., Witte DR., Jorgensen ME., Johansen NB. Higher physical activity is associated with lower aortic stiffness but not	Cross-Sectional	No	ADDITION-Pro Study, Danish Adults. 40-69y without known diabetes.	Participants with self-reported history of CVD. Missing measures of outcome variables	Accelerometer & Heart Rate	Submaximal step test used to estimate individual calibrations (n=941), group calibration used on those without submax test (n=463)	Arterial Stiffness, Central SBP, Central PP	Model 1: sex, age, HR and meanBP. Model 2: +WC. Model 3: +smoking, TG, antihypertensive or lipid lowering meds, and incident diabetes.	1404	M: 66.4(62.1,71.3). F: 66.1(60.7,71.1).	(1) Substitution of 1 hr SB with 1 hr LPA, (2) substitution with only participants without type 2 diabetes or taking BP or lipid meds.	No significant effect of substituting 1 hr LPA or MVPA on aortic pulse wave velocity, central SBP, central PP.

with central blood pressure: the ADDITION -Pro Study. 2015.												
Sugawara J., Inoue H., Hayashi K., Yokoi T., Kono I. Effect of low-intensity aerobic exercise training on arterial compliance in postmenopausal women. 2004.		Yes	Normotensive, nonsmokers, did not take meds, have significant intima-media thickening, plaque formation, and or characteristics of atherosclerosis.				Arterial compliance, distensibility, BP, PP		15	LPA 58 (4), MPA 59 (6)	Change post-training in total CHL, LDL, artierial compliance, distensibility (all other variables no signifiicant)	Pre, Post. Total HDL 40%: 236(18) mg/dL, 218(22). LDL 142(15) mg/dL, 127(23), arterial compliance 0.70(0.32) mm2/mm Hg, 1.06(0.55), distensibility coefficient 2.3(0.9), 3.4(1.8). All Significant.

Wang H., Zhang T., Zhu W., Wu H., Yan S. Acute effects of continuous and interval low-intensity exercise on arterial stiffness in healthy young men. 2014.	Randomized balanced self-control crossover design	Yes	Active, normotensive, and non-smoker. Not taking any medications for diabetes, metabolic disease, or CVD. No history of any disease known to affect the cardiovascular system.				Systemic arterial stiffness, blood pressure		15	21.2(0.4)	2-factor ANOVA (treatment and time) with repeated measures.	Significant interaction effect (time x treatment), main effect for time, and main effect for treatment for both treatments. CAVI was significantly lower than CON with IE treatment at 60 min post-exercise, non-sig difference between CON and CE at 60 min.
Cancer Risk												

Dallal CM., Brinton LA., Matthews CE., Lissowska J., Peplonska B., Hartman TJ., Gierach GL. Accelerometer-based measures of active and sedentary behavior in relation to breast cancer risk. 2012.	Case-Control	No	NCI Polish Breast Cancer Case-Control Study. Women aged 20-74 years in Poland from 2000-2003. Controls randomly selected from Polish Electronic System.	Currently pregnant. Tumor histology other than in situ or invasive.	Accelerometer	SB <100, light 100-159, MVPA 760+. Overall activity - TAC. Worn all waking hours. Excluded if <10 hrs wear. Analyzed if 1 valid day.	Breast Cancer risk	Age, BMI, education, smoking status, age at menarche, number of full term births, breast cancer family history, previous screening mammography, history of benign breast disease, menopausal stage, wear time.	Cases n=996, Controls n=1164	Cases 30.6% 25-49y, 69.4% 50-75; Controls 29.6% 25-49y, 70.4% 50-75y.	Relation between LPA (min/d) and breast cancer. Multivariable adjusted (for covariates listed) OR.	<225.12 min/d 1.00, 225.13-265.77 min/d 0.71 (0.56, 0.90), 265.78-305.41 min/d 0.56 (0.43, 0.72), >305.42 min/d 0.47 (0.35, 0.63)/ p-trend <0.0001.

Kobayashi LC., Janssen I., Richardson H., Lai AS., Spinelli JJ., Aronson KJ. A case-control study of lifetime light intensity physical activity and breast cancer risk. 2014.	Case-Control	Yes	Molecular Epidemiology of Breast Cancer (MEBC), female breast cancer case-control study in Canada from 05-10. Aged 40-80 years, diagnosed with incident in situ or invasive breast cancer diagnosis and no cancer history. Controls: residing in same geographic area, screening mammography program.		Questionnaire		Breast Cancer risk	age, ethnicity, education, primary family breast cancer history, age at menarche, lifetime oral contraceptive use, pregnancies, number of live births, age at first pregnancy, ever breastfed, HRT, BMI, cigarette smoking in pack-years, alcohol consum	Pre cases 338, pre controls 442, post cases 722, post controls 730	pre cases 47.0(4.0), pre controls 47.1(4.2), post cases 62.6(8.2), post controls 62.5(	Associations (adjusted OR) between lifetime LPA and risk of pre- and post-menopausal breast cancer. Pre-adjusted for age, center, education, ethnicity, BMI, MVPA and contraceptive use. Post-adjusted for age, center, education, ethnicity, BMI and MVPA.	No significant trend shown in increasing quartile of LPA in each age period, pre- or post-menopause.

								ption, min MVPA.		7.9)		
Functional Health												
Blair CK. Morey MC., Desmond RA., Cohen HJ., Sloane R., Snyder DC., Demark-Wahnefried W. Light-intensity activity attenuates functional decline in older	Cross-Sectional & Longitudinal	Yes	RENEW trial - randomized control trial to evaluate a 1-yr diet and exercise intervention. Eligibility: >65 y, >5 yr from diagnosis of breast, prostate, or colorectal cancer, <150 min/wk of		Questionnaire		Function	height, weight, common medical conditions, signs and symptoms, cancer treatment, diet	641	73.1(5.1)	Cross-sectional association association (ANCOVA) between Tertiles total LPA, LLPA, and HLPA and physical function (adjusted for age, sex, BMI, comorbidities,	SF-36 PF subscale score total LPA sig diff Q1-Q3. No sig diff in LLPA, HLPA. Basic lower extremity function subscale score total LPA sig diff Q1-

cancer survivors. 2014.			strength and/or endurance MPA, no contrainidications to exercise, English speaking and writing.								symptoms, and other intensities).	Q3. No sig diff in LLPA, HLPA. Advanced lower extremity functional subscale score total LPA sig diff Q1-Q3 and HLPA Q1-Q3. No sig diff LLPA.
											Association between change in HLPA (no change or decrease in MVPA) and change in PF (adjusted for age, sex, BMI, comorbidities, signs and symptoms.	Sig increase (0.44) in physical function score compared to reference group (no change or decrease in HLPA and MVPA). HLPA increased 12.6 (6.9, 22.0)

												MET-h/wk
Henchez Y., Bastardot F., Guessous I., Theler J., Dudler J., Vollenweider P., So A. Physical activity and energy expenditure in rheumatoid arthritis patients and matched controls. 2012.	Cross-Sectional	No	RA (according to 1987 ACR criteria, ACR functional classes I-III, aged 40-80, stable disease-modifying anti-rheumatic drug regimen last 3 months. Controls randomly matched to RA patients on 5 yr age group and gender.		Questionnaire		Rheumatoid Arthritis (vs controls)	age, sex, weight, and height	99	n=5840-59y, n=5260-80y	Energy expenditure of low-intensity (<4 BMR) in RA patients and controls. (corrected for age, sex, weight, and height.	RA patients 2198 (2130, 2265) kcals/d. Controls 2198 (2161, 2234) kcals/d. p=0.242. (sig diff in EE in moderate intensity)

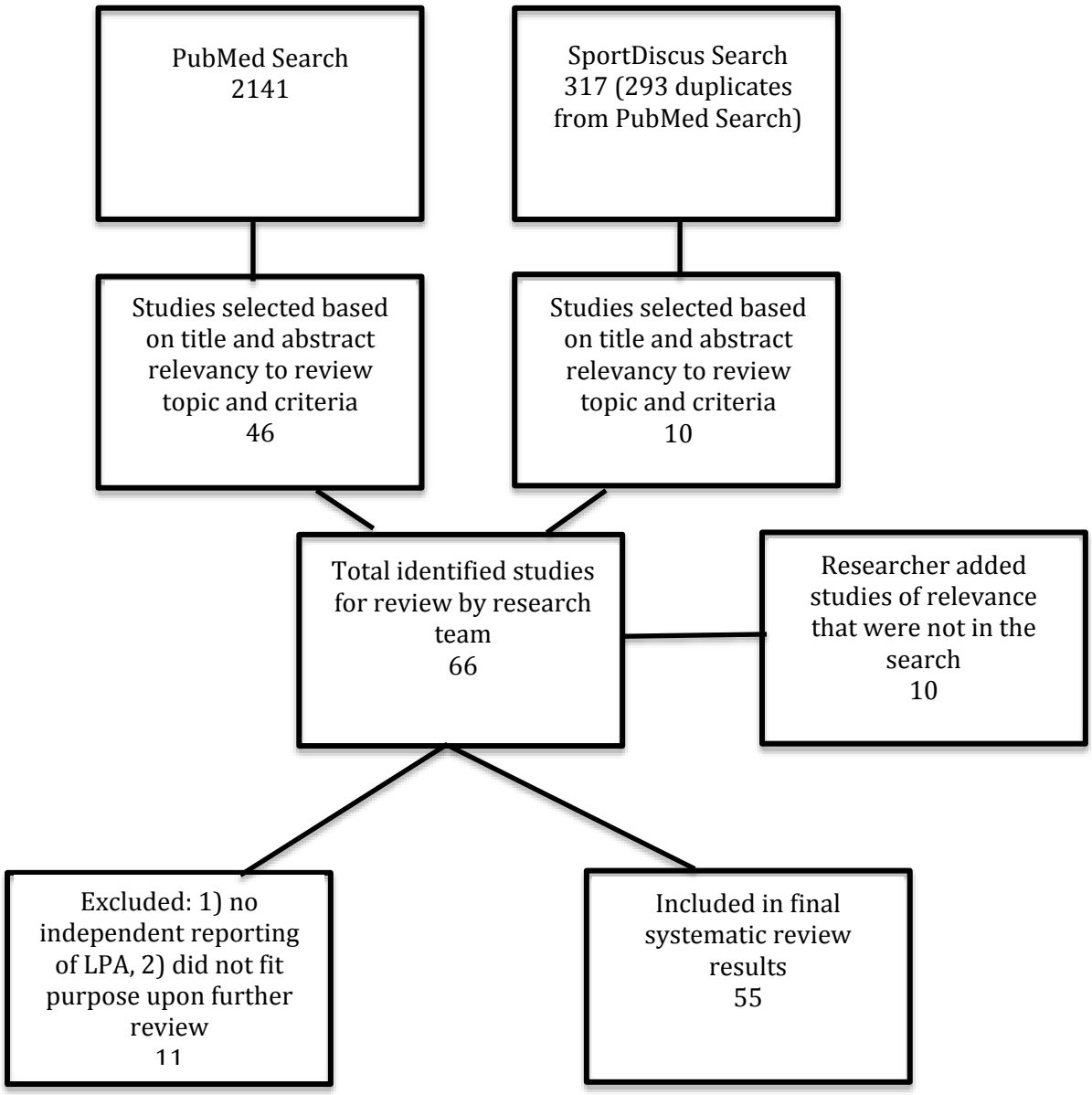
Laudani L., Vannozzi G., Sawacha Z., Croce U., Cereatti A., Macaluso A. Associations between physical activity levels and physiological factors underlying mobility in young, middle-aged, and older individuals living in a city district. 2013.	Cross-Sectional	No		Individuals who engaged in regular training or sport practice (3+ times per week, for more than 60 min/time)	Accelerometer		Coactivation, peak torque, rate of force development, peak power		72	young 28 (2)y, middle 48 (2)y, old 70 (3)y	Effect of low intensity on physiological factors underlying mobility.	Coactivation of flexors (during extension): LPA sig > than MPA and HPA. Peak Torque: LPA during extension and flexion MVC sig < than MPA and HPA. Rate of force development during flexion MVC: LPA sig < than MPA and HPA. Peak power during CMJ and STS sig < than MPA and HPA.

Lee S., Yuki A., Nishita Y., Tange C. Relationship between light-intensity physical activity and cognitive function in a community-dwelling elderly population - an 8-year longitudinal study. 2013.	Longitudinal	Yes	National Institute for Longevity Sciences - Longitudinal Study on Aging in Aichi, Japan.		Questionnaire		Cognitive Decline	age, sex, education, BMI, initial MMSE score, smoking status, self-rated health, CES-D score, sleep duration, occupation, hypertension, MI, Hyperlipidemia, diabetes, stroke, RA, MVPA.	550		Odds of significant cognitive decline during follow-up period according to LPA quartile. (Model 3 - adjusting for all covariates)	OR: 2nd 0.58 (0.28, 1.2), 3rd 0.53 (0.25, 1.12), 4th 0.39 (0.18, 0.83) p trend = 0.02.
Loprinzi PD., Brosky JA. Objectively measured physical activity	Cross-sectional	No	NHANES 03-04, aged 40-85y.	Missing balance (did not participate in balance measure if unable	Actigraph 7164	SB <100, MPA >2020, VPA >5999. Wear time >60 min	Functional balance (completion of all 4 conditions), or dysfunctio	Age, gender, race-ethnicity, education, comorbi	1831	61.3 (60.7, 61.9)	LPA in functional balance and dysfunctional classification	Functional 352.5 min/d, dysfunctional 319.8 min/d (p<0.05)

and balance among US adults. 2014.				to stand on their own, current dizziness or lightheadedness, weighed >275, could not fit into standard gait belt, required a leg brace to stand, or had lower limb amputation) and covariate data, insufficient accelerometry data		consecutive 0s. Four valid days (>10 hrs)	nal balance	ties (0 or 1+), vision or hearing problems, meds, BMI			Multivariate logistic regression LPA (OR (95% CI) for functional balance (referent group dysfunctional balance)	50-59 vs 40-49y 0.32 (0.17, 0.56), 60-69 vs 40-49y 0.25 (.13, 0.49), 70+ v 40-49y 0.10 (0.06, 0.21), women v men 0.99 (0.78, 1.25), BMI 1.04 (1.02, 1.07), Comorbidities v none 0.75 (0.49, 1.14)

Ramadi A., Stickland MK., Rodgers WM., Haennel RG. Impact of supervised exercise rehabilitation on daily physical activity of cardiopulmonary patients. 2015.	Prospective one group pretest-posttest study	No	>60 y, medically stable, receiving medical therapy, and able to participate in exercise.	1) exercise limiting non cardiopulmonary comorbidity, 2) uncontrolled hypertension, 3) unstable cardiac disease or previous CABG, 4) recent respiratory exacerbation, 5) required supplemental oxygen, 6) cognitive dysfunction, 7) profound language barrier.	Accelerometer		Exercise capacity		37	74.6(6.2)	Correlations between change in 6 min walk distance and LPA	r=0.067, p=0.698 (no PA metric significant)

Figure 1. Review Study Selection



CHAPTER 4: CONTEXTUAL AND PATTERN ANALYSIS OF PHYSICAL ACTIVITIES IN OLDER ADULTS

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Abstract

Purpose: 1) to elucidate the pattern of light intensity physical activity (LPA) in older adults, and 2) to identify the activities, domains of activities, locations of activities, and social interaction patterns specific to LPA. Methods: Forty-five adults, 60 y and older wore a hip-worn and wrist-worn activity monitor for 7-days, all-waking hours. On one day participants completed a physical activity diary and a subsample (n=22) wore a wearable camera to determine activity type and context of activity. Individualized cutpoints were used to determine time spent in LPA and these data were aligned with diary and camera data to determine activity type and context during light intensity. Results: An average of 255.3±9.8 min of LPA as measured by the hip-worn activity monitor and 307.0±18.4 min of LPA as measured by the wrist-worn monitor were recorded. Minutes of LPA were accumulated in short bouts (~2 min per bout), distributed evenly over the course of the waking day, with no bout per hour in excess of five minutes. During LPA, leisure-time activities were the most commonly performed activity domain accounting for 47% of the time, followed by household activities accounting for 35% of LPA time. The two most prevalent activities within the leisure-time domain, multi-tasking while watching television and using the computer combined for 29% of leisure-time activities. General household activities and cooking accounted for the most prevalent household activities performed. Overall, more light intensity activities were performed inside versus outside and alone versus with others. Conclusion: Results show LPA, the most prevalent of the active behaviors, occurs in short, frequent bouts throughout the day. Additionally, we found leisure-time activities, especially those traditionally

considered sedentary activities, were performed with sporadic LPA or while "multitasking" making up a predominant proportion of time spent in LPA. These results provide evidence to aid in future development of appropriate LPA activity prescription (FITT principle), providing information on the when, what, where, and how much of LPA in older adults.

Introduction

Recent research has highlighted the importance to considering the entire spectrum of physical activity intensity when considering physical activity related health benefits, including light intensity physical activity (LPA) (21, 54). LPA has historically not been viewed as impactful to health, however, recent research has revealed the independent benefit that engaging in LPA can provide (61, 84). Although there appears to be benefit to adding additional LPA into our daily routines, little is known about the nature of light intensity physical activities.

Understanding the patterns of activity intensity and what activities fit within each category is important. Physical activity recommendations are not a 'one size fits all' prescription as is illustrated by our current physical activity guidelines with recommended time spent in activity differing by intensity level. LPA is an important alternative for older adults who may not be comfortable, or able to perform more vigorous activities. Additionally, LPA may provide an important stepping-stone to future engagement in more intense exercising behaviors in the future. Since older adults have previously been shown to be one of the least active segments of the United States population, providing a more informative view of LPA in older adults could prove to be impactful for overall older adult population health in the future.

To our knowledge, one previous study has reported the most common light intensity activities using the time use survey and the compendium of physical activity to assign intensity categories (136). Their results suggest the majority of time spent in light intensity activities, as identified by the compendium, are within the household domain, such as personal care and cleaning. The time use 24-hr

recall, survey data is a useful tool indicative of how we spend our time, however it does not distinguish between actual intensity level of the activity being performed or provide us with further contextual information such as where these activities are most commonly performed and with whom are these activities most commonly performed. Amassing further descriptive information on LPA is important because we need to understand how much LPA is being performed and how that LPA is being accumulated in order to begin to design LPA prescription or to further strengthen studies examining LPA and it's association with health variables. Providing a basis for what activities constitute light intensity will also aid in what activities should be recommended to those who need to begin to increase their activity levels, in addition to offering evidence to create more robust measures of LPA.

No previous study has sought to objectively identify time spent in light intensity, in addition to simultaneously measuring the activity performed, location of the activity, and whether or not another individual accompanied the older adult. Therefore our purpose is twofold, 1) to elucidate the pattern of LPA in older adults, and 2) to identify the activities, domains of activities, locations of activities, and social interaction patterns specific to LPA. We hypothesized 1) older adults would spend a larger proportion of their time in LPA in the morning hours versus the afternoon hours and LPA would be performed in short, sporadic bouts versus long, sustained bouts since LPA activities previously identified are largely our everyday ubiquitous activities and 2) household-related activities will be the most prevalent LPA performed by older adults (136). Further, research has shown older men and

women participate in differing amounts of LPA, therefore we examined results by gender to test for potential differences between males and females (144).

Methods

Participants. Participants were recruited from a large Midwest, metropolitan city and the surrounding community, including local senior centers, older adult programs, senior residential communities, and campus resources, by word of mouth, announcements, e-mails, and flyers. Eligibility was established over the phone or in person. Individuals were included in the study if they were 60 years or older. Participants were excluded from the study if they were non-English speaking, unable to walk for 3-minutes unassisted, or had any lower limb limitations that would affect the accuracy of the physical activity monitor assessment (e.g. amputations, walking aids) (Appendix C). No power analysis was needed for the current study because the main purpose of this study was to describe the number of times LPA activities are performed with no significance testing; the resultant sample size is in accordance with previous prevalence studies reporting the results of a primary data collection (31, 96, 118).

Overview. This study was a 7-day observational study. Data collection consisted of two different visits with the research staff in the community or at the Physical Activity and Health Research Laboratory on the university campus, chosen based on the participant's preference. Community sites included local establishments (n=6) or community senior centers (n=6). During the first visit, qualifying participants reviewed and signed an informed consent document

approved by the university's Institutional Review Board (Appendix D). Participants completed a health history questionnaire (Appendix E), the Edinburgh handedness inventory (Appendix F), and had their height and mass measured following standard procedures (108). All participants were asked to complete a 7-day physical activity monitoring period. Two activity monitors, an activity log, a physical activity diary, and a wearable camera (subsample) were issued to each participant. Following this monitoring period, all activity assessment tools were collected from the participant during the second visit. At the second visit they were also asked to complete a nine-minute walk test while speed, oxygen consumption, and acceleration were measured.

7-day Monitoring Period. Participants were asked to wear two activity monitors for seven consecutive days, during all waking hours. In addition, participants were given an activity log (Appendix G) to record the times they put on and took off the activity monitor and any planned exercise time they engaged in during the monitoring week. On one day of the monitoring week, participants filled out a physical activity diary (Appendix I) and a subsample, identified by those participants who were willing to wear the camera, wore a wearable camera for one day (the same day the diary was completed).

Activity Monitors. Participants were asked to wear two Actigraph GT3X+ activity monitors (Actigraph Corp., Pensacola, FL). One activity monitor was worn at the anterior iliac spine on the anterior axillary line. Monitors were placed on a belt and worn on the right side of the body for all participants. The second monitor was worn on the participants' non-dominant wrist secured between the ulnar and radial

processes by a manufacturer provided Velcro strap (Appendix H). Actigraph accelerometer-based activity monitors are the most commonly used activity monitor and have been shown to provide valid and reliable activity information in a large age range and over multiple intensity categories at the hip site (41, 50, 105). Activity monitors were initialized to collect data at 100 Hz. Upon analysis activity data were aggregated into 60-second epochs. Time spent in LPA and LPA bouts were calculated using individually-derived cutpoints developed using data obtained during the 9-minute walk test. Accelerometer counts per minute and corresponding energy expenditure were averaged over each speed completed during the 9-minute walk test. These data were plotted for each participant separately and the slope and intercept was determined. These equations were then used to calculate for the light intensity (1.5 METs) cutpoint (accelerometer counts per min) and the moderate intensity (3.0 METs) cutpoint (accelerometer counts per min). Accelerometer data were collected from the hip and wrist individually, therefore individualized cutpoints were developed for each participant for the hip activity monitor and for the wrist activity monitor. Hip data was analyzed using the vertical axis and the cutpoint for delineating sedentary time from light intensity was 100 counts per min for all participants. Wrist data were analyzed using the vector magnitude and both lower and upper bounds of light intensity were calculated individually. For both wear locations activity monitor wear time was determined by a combination of the Choi algorithm and wear logs, which has shown to provide the greatest accuracy (26, 66). Valid days were determined using standard hip procedures for both wear locations (134).

Physical Activity Diary. Participants were provided a physical activity diary that they were asked to record each action they perform for one full day during their waking hours. Participants recorded the behavior performed (e.g. walking, sitting and reading, etc), location (e.g. kitchen, outside), and companionship (e.g. with sister) throughout the day as the activities were performed. Diary data were aligned with hip-worn activity monitor data by time in order to identify minutes of LPA. These data were both in minute-by-minute format and analyzed as such. In order to meet the aim of the proposed study, the data from the diary was used to determine activity frequency and domain frequency based on the self-reported diary. Light intensity activity type, location, and social interaction were scored by frequency (number of LPA minutes) to determine the percentage of time spent in each light intensity activity providing information on the most commonly performed light intensity activities.

Wearable Camera. A convenience subsample determined by those participants willing to wear the camera, wore a camera (Sensecam, Vicon, Oxford, UK) attached to a lanyard, around their neck, on the same monitoring day they completed the physical activity diary (Appendix J). The camera was positioned in the center of the upper portion of the chest and took still shot pictures every 20 seconds with each position or lux change and every 50 seconds with no movement change. Further information regarding the camera can be found elsewhere (68). Participants were instructed to turn the camera on when they woke up and wear the camera until the camera's battery died (maximum lifespan: ~10 hours). A "private" button was available that allowed participants four minutes of unrecorded time

when necessary (i.e. bathroom). The data collected from the cameras was used to supplement the information from the physical activity diaries as the camera may provide a more objective record of activity. Activity, location, and social interaction were recorded from the pictures using the Doherty Browser and following standard annotation rules (32). Camera data were aligned by time with hip-worn activity monitor data in order to identify minutes of LPA. These data were both in minute-by-minute format and analyzed as such. These data were used to determine the percentage of time spent in each light intensity activity type and domain to provide information on the most commonly performed light intensity activities (68).

9-minute walk test. During the second visit, participants were asked to complete a nine-minute overground walk while wearing a portable metabolic system (Cosmed K4b^2, Cosmed Inc. Rome, Italy) to measure oxygen consumption. The nine-minute walk consisted of 1) three minutes walking at a pace slower than their normal walking pace, 2) three minutes walking at their normal walking pace, and 3) three minutes walking at a pace faster than their normal walking pace. The accelerometer-derived counts per minute and oxygen cost data were used to determine each individual's counts per minute in order to delineate intensity categories during their 7-day monitoring period data. Previous research has suggested adult activity monitor analysis techniques do not adequately account for changes in maximal oxygen uptake as one ages, thus misclassifying activity intensities in those over 65 years, therefore this method provided an individual accelerometer calibration for each participant (48, 128). Metabolic equivalents

(MET) were determined using 1 MET = 3.5 ml/kg/min. The light intensity activity classification was 1.5 to 2.99 METs.

Portable Metabolic System. The Cosmed K4b^2 is a portable metabolic system and battery pack that can be worn by a participant on a harness secured to their trunk. The portable unit is a small (170x55x100 mm) and lightweight (400g) device that secures onto the individuals chest, while the small battery (120x20x80 mm) is strapped on the upper back. Oxygen and carbon dioxide are sampled from the facemask covering the participant's nose and mouth and a turbine attached to the facemask provides ventilation information. Breath-by-breath data was downloaded and averaged into one-minute data points. The Cosmed K4b^2 has been shown to be a valid measure of oxygen uptake during exercise (106). The Cosmed K4b^2 showed small differences in VO_2, ranging 0.088-0.092 L/min, when compared to the Douglas bag method.

Statistical Analyses. Statistical analyses were conducted in SPSS version 22 (IBM, Chicago, IL). Descriptive statistics were used to describe the study sample and the mean and standard error of LPA and LPA bouts over the 7-d monitoring period. Frequencies were calculated to describe the number of occurrences of different light intensity (as defined by the hip activity monitor) activities or activity domains as measured by the activity diary and wearable camera. Physical activity diary/camera data and hip activity monitor data were aligned by time, minute-by-minute for the waking monitored day. Results are reported as total number of minutes complied by all participants. Finally, the sample was split by gender and independent sample t-tests will be used to test for differences in activity level or LPA activity frequency

between men and women. For testing gender differences, we used an alpha level of 0.05 for analyses.

Results

Fifty participants contacted the researcher for further study description, 46 participants were interested in volunteering for the study and all met inclusion criteria. Following screening, one participant chose not to pursue study participation further due to scheduling conflicts. Forty-five older adults completed the observation protocol with complete and valid data. Descriptive statistics for all participants (N=45) are reported in Table 9. In summary, participants were on average 70.9±0.7 y, overweight (BMI 27.1±0.6), and 68.9% were female. Twenty-two (64% female) older adults volunteered to wear the camera simultaneously while recording their activity in the physical activity diary.

How Much Time Spent in LPA

Individualized cutpoints were developed for intensity category analysis of both the hip and the wrist wear sites. Hip cutpoint delineating light intensity from moderate intensity averaged 2336 counts per min, with a range of 860 to 5348 counts per min. Lower bound wrist light intensity cutpoints delineating sedentary time from light intensity averaged 1859 counts per min with a range of 99 to 6870 counts per min. The upper bound cutpoint to delineate light intensity from moderate intensity activity averaged 5467 counts per min, with a range of 1918 to 17644 counts per min. All participants met the wear criteria, averaging 873.2±9.4

min per day of wear time per day of wear (6.9±0.1 days) at the hip site and 877.0±9.4 min per day of wear time per day of wear (6.9±0.1 days) at the wrist site.

Over the 7-d monitoring period, older adults in this study engaged in an average of 255.3±9.8 min of LPA as measured by the hip-worn activity monitor and 307.0±18.4 min of LPA as measured by the wrist-worn monitor, corresponding to 27.2±2.0% and 36.6±2.1% of their waking day (Table 10A and B). On average, older adults spend about 2.5 minutes in each bout of LPA, therefore they occur quite frequently throughout the day (hip-worn: 260.2±9.2 occurrences; wrist-worn: 244.6±14.2 occurrences). When number of bouts are examined for each hour of wear time hip data shows 5 to 9 bouts were performed per hour, averaging 2.5 to 5 min per bout between 7:00AM and 7:00PM (Figure 2A-B). Wrist data showed similar results, displaying 6 to 9 bouts performed each hour, in 2 to 5 min per bout between 6:00AM to 7:00PM (Figure 2C-D). The wrist data show a higher bout duration during the early morning hours (6:00AM – 7:00AM) flattening out to about 2 to 3 min in duration until 7:00PM.

When results were broken down by gender, males and females tended to accumulate similar amounts of LPA in similar patterns with no variables indicating a significant difference.

When Does LPA occur

Figure 3 (A: hip-worn activity monitor; B: wrist-worn activity monitor) shows the average minutes of LPA that occurred at each hour of the day for each day of the week. Although they show differing stagger patterns, both sites depict 15-30

minutes spent in LPA each hour between the hours of 7:00am and 7:00pm, which equates to 25-50% of the time. The wrist-worn monitor showed higher peaks during the morning hours, noon hours, and evening hours, possibly when household tasks were more prevalent (i.e. cooking breakfast/dinner, personal care, etc.) and upper body movement was more pronounced compared to hip movement.

What Are the Most Prevalent Light Intensity Activities

Physical activity diary data included all 45 participants, which compiled a collective 10,661 minutes of LPA. When broken out by gender, collectively, men engaged in a sum of 3,111 minutes of LPA and women in a sum of 7,550 minutes of LPA. The subsample of camera data (n=22) collected a combined 2,895 min of LPA, with men accumulating 1,351 minutes and women accumulating 1,544 minutes of LPA. These collective minutes were used to obtain the frequency of light intensity activites.

When examining the most prevalent activity domain, just under half of the total recorded LPA took place in the leisure time physical activity domain (47%) (Table 11A and B). The most commonly reported (diary) and recorded (camera) leisure time activities were 'multitasking while watching television' and 'shopping.' The next most dominant domain was household activities making up about 35% of the total recorded LPA time. Cooking occurred frequently with 23% (diary) and 19% (camera) of the household time. Both measurement methods also revealed high amounts of LPA time spent completing continuous, general household tasks. The physical activity diary reported 14.9% of total household activity and the

camera recorded 54.5% of the household activity time spent in general household tasks. The 'general household activity category' shows large variation between measurement device, which could be due to the annotation rules used to annotate the wearable camera pictures as an event. A number of household activities (ex. cooking, cleaning, dishes) did not occur for long enough duration to constitute an individual event therefore a large number of these activities were annotated by the camera data as "general" activity.

Again, there were few differences between genders engaging in light intensity activities. The camera data recorded a significantly higher percentage of males completing general household tasks (62.4% versus 49.1%) and females recording a greater percentage of shopping time (24.8% versus 3.3%).

Where Do Light Intensity Activities Take Place

Location of activity was reported in the physical activity diary and recorded by the researcher from the camera data. Diary results indicate that about 75% of light intensity activities occur inside (Table 12 A and B). Similar results were captured by the camera, which reported 79% of the light intensity activities occurring inside. The diary data revealed a significant gender differences in location of LPA, with females tending to undertake more activity inside (80.3% versus 65.5%, p=0.01) and males performing outdoor activities (31.8% versus, 17.7%, p=0.01).

With Whom Do Light Intensity Activities Occur

Table 12A and 12B also provides the results regarding social interactions that occur during light intensity activities. The camera data indicated over half of the time spent in LPA, the participant appeared to be alone. The diary data, which provided more detailed information, such as social relation, still showed 43% of LPA occurrences to be solitary. The participants reported by physical activity diary over half of their LPA time interacting with someone, with the most time spent interacting with a spouse (22.3% of the time). There were no gender differences for either measurement method.

Discussion

This study sought to provide further insight into the pattern of LPA in older adults. Initially, we examined the overall time per day spent in LPA per day and the percentage of their total waking day. The results from the 7-d monitoring period garnered similar results to those obtained from large, population-based studies. For example, data from the National Health and Nutrition Examination Survey show adults 20 years and older averaging about 37% of their time in LPA (115). More specific to older adults, Martin and colleagues examined proportion of time spent in LPA in older adults with about 30% of their waking day spent in LPA; this time in LPA gradually decreasing with increasing age (101). Our results more closely mirror Martin et al. results, likely due to the similar population, providing evidence to the importance of independent analyses of activity levels in older adults. These results indicate the majority of older adults' active time is spent in LPA, providing increased pull for continued research for the elucidation of LPA.

This study extends the current prevalence research by examining how the time spent in LPA is accumulated throughout the waking day. Results revealed LPA is on average accumulated in bouts of about 2.5 min that are frequently occurring with an average of about 14 min spaced between each LPA bout. These weekly average results of short, frequent bouts are confirmed when examined more narrowly by distribution across time of day. Hip and wrist data both report no bout per hour in excess of five minutes. The short duration of these bouts may make accumulation of time in LPA easier to obtain compared to longer duration activity bouts; however, this begs the question whether these short LPA bouts would provide a benefit to health. Experimental research investigating the metabolic effect of incorporating 2 min of light intensity walking every 20 minutes showed a significant decrease in post-prandial glucose area under the curve (35). Even though activity patterns show LPA is accumulated in short bouts, these experimental results suggest increasing the number of bouts accumulated in a day, in short durations, could provide a health enhancing effect.

In order to investigate how LPA was accumulated we examined the time of day pattern of LPA for each day of the week (Figure 3 A & B). Our results similarly mirrored those published by Martin and colleagues however our data showed no clear bimodal pattern (101). Both measurement methods provided evidence for a consistent 15 or greater min of LPA each hour from waking time until about 7:00pm. This finding is of particular interest. When time of day data for moderate and vigorous intensities are examined from a previous study, in addition to being in a much smaller proportion, MVPA tends to peak in the first half of the day and fall

towards the second half of the day (101). Upon waking, there is an increase in time spent in LPA each hour with a leveling off across the day, suggesting there may be a lower inhibitory effect of daily fatigue with LPA in older adults, which could be a beneficial consideration when designing physical activity prescriptions in older adults.

There were evident differences in results between the physical activity monitor measurement location. The most apparent differences are seen in Figure 2A-D and Figure 3A and B where time of day is being examined. A criticism of hip worn activity monitors are their inability to detect upper body movement, therefore it is interesting the time of day figures show spiked data during times when upper body activities may be more prevalent. This may possibly result in LPA classification from the activity monitor versus sedentary behavior. These differences may also account for the greater average min of LPA recorded by the wrist activity monitor versus the hip, although they are within 40 min of one another.

This study is the first to objectively identify time spent in light intensity activity by identifying LPA using the activity monitor and simultaneously tracking the activity being performed by use of the physical activity diary and wearable camera. One previous study has linked the time use survey, a 24-hr recall survey, with MET levels from the compendium to rank order the most commonly performed activities in each intensity category (136). Although we identified light intensity in different ways, when comparing results from this previous study and our study, similarities in predominant activities arise such as personal care, socializing, general housework, cooking, and laundry. Out of the ten most commonly performed LPA

activities identified by Tudor-Locke et al., 60% of them were household-related, leading to the perception that light intensity activities are the 'household activities' (136). However, our results indicate, in older adults, a larger percentage of the time spent in LPA was within the leisure-time activity domain. Additionally, a pattern of multi-tasking while undertaking traditionally sedentary tasks, such as eating, reading, computer work, and watching television, resulted in classification of time within these activities as LPA since movement was occurring. Therefore these activites emerged as important and prevalent LPA activities; making up almost half (45.6%) of the leisure-time.

Understanding where these light intensity activities most commonly take place and whether they occur with social interaction have important behavioral considerations when identifying or developing behavior change interventions. Results from the current study indicate over three-fourths of LPA occurs inside, which may also be indicative of the large number of identified activities that take place indoors. However, this is an important distinction given often cited barriers to physical activity in older adults includes lack of outdoor resources such as sidewalks, benches, or proper lighting, and lack of transportation (19, 70). This suggests, activity prescriptions could incorporate indoor activities to alleviate potential location barriers. Another barrier to moving older adults from an inactive to active lifestyle includes lack of social support. According to the diaries, just over 40% of light intensity activities are performed alone, again providing preliminary evidence an LPA adherence may be effective when activities are completed alone as

opposed to with others. LPA may be activities that could challenge these barriers by providing options that could be performed in home or performed without others.

It was hypothesized there may be gender differences in LPA, as previous research has shown older women's LPA tends to decline at a less rapid rate when compared to men, however, we did not observe a significant difference in time spent in LPA between men and women (144). Additionally, these results were in contrast with time use surveys examining time spent in leisure-time moderate or vigorous exercising activities, which reported leisure-time activity differences by gender in LPA (139). For example, men tended toward more sport activities, while women tended toward more aerobic, group activities.

One of the major strengths of the current study is the simultaneous, objective measurement of all study variables: intensity, activity, location, and social interaction. Additionally, the use of individual cutpoints enhances our results since intensity was the main focus of the study it was important we attempted to adjust for known errors in generalizing adult-based cutpoint methods to older adult populations. A limitation to the current study includes the use of 3.5 ml/kg/min instead of measuring resting metabolic rate. Additionally, using the standard LPA metabolic equivalent ranges to calculate individual cutpoints instead of performing a maximal graded exercise test, however our intention was to be inclusive of all health backgrounds, providing a more generalizable picture of older adults, therefore maximal graded exercise tests are not always recommended dependent on the condition. Additionally, the study sample was somewhat homogenous

(mostly white, high income), constraining generalizability to all older adult populations.

Conclusion

This is the first study to objectively identify time spent in LPA, in addition to simultaneously measuring the type of activity performed, location of the activity, and whether or not another individual accompanied the older adult. We found LPA is completed for a consistent amount of time each hour from about 7am until 7pm, unlike other active behaviors. Additionally, we found LPA in older adults was accumulated in frequent, short duration (~2.5 min) bouts over the course of the day. We identified the activities performed, and our results challenge the possible misconception light intensity activities are only "household' activities, as our results indicate the majority of the LPA activities performed by older adults were leisure time activities. As more research is being released promoting the health-related benefits to participating in LPA, these results provide behavioral evidence to understand how we can incorporate and build LPA into older adults' lives.

Table 9. Participant Descriptives (Mean(SE) or %) N=45

Age	70.9(0.71)
Height (cm)	164.6(1.2)
Mass (kg)	73.3(1.9)
BMI (kg.m2)	27.1(0.6)
Gender (% Male)	31.1%
Education	
High School	11.1%
College	42.2%
Graduate School	46.7%
Race	
White	93.3%
Hispanic	4.4%
African American	2.2%
Annual Income	
$5,000-$15,000	2.2%
$15,000-$25,000	2.2%
$25,000-$35,000	4.4%
$35,000-$50,000	13.3%
>$50,000	68.9%
Did Not Respond	8.9%
Health History	
High Blood Pressure	48.9%
Heart Problems	26.7%
Arthritis	44.4%
Diabetes	11.1%
Leg Pain	6.7%
Lung Problems	6.7%
Back or Joint Problems	26.7%
Cancer	20.0%
Physical Activity (hip-worn activity monitor)	
Sedentary (min/wk)	3843.1(94.6)
Moderate Intensity (min/wk)	185.6(46.1)
Vigorous Intensity (min/wk)	11.8(5.8)

Table 10A. Accelerometer-determined light intensity physical activity in older adults: hip-worn activity monitor

	Hip-Worn Activity Monitor						
	Total Sample (N=45)		Male (n=14)		Female (n=31)		p-value*
	Mean	SE	Mean	SE	Mean	SE	
Minutes Per Day	255.3	9.8	259.2	19.5	253.6	11.5	0.79
Percent of Day (%)	27.2	2.0	23.9	3.4	28.7	2.4	0.27
Average Number of LPA Bouts per day	260.2	9.2	267.3	19.2	257.2	10.5	0.63
Average Time Spent in LPA Bouts (Min/d)	2.9	0.1	4.0	2.8	2.9	0.1	0.63
Average Wear Time (Min/d)	873.2	9.4	903.7	16.9	859.5	10.6	0.03
Average Number of Days Worn	6.9	0.1	6.9	0.1	7.0	0.1	0.30

*gender differences

Table 10B. Accelerometer-determined light intensity physical activity in older adults: wrist-worn activity monitor

	Wrist-Worn Activity Monitor						
	Total Sample (N=45)		Male (n=14)		Female (n=31)		p-value*
	Mean	SE	Mean	SE	Mean	SE	
Minutes Per Day	307.0	18.4	300.0	24.5	310.1	24.5	0.80
Percent of Day (%)	36.6	2.1	35.8	2.8	36.9	2.8	0.79
Average Number of LPA Bouts per day	244.6	14.2	244.5	50.5	244.6	110.6	0.79
Average Time Spent in LPA Bouts (Min/d)	2.4	0.2	2.3	0.4	2.4	1.2	0.99
Average Wear Time (Min/d)	877.0	9.4	892.6	19.6	870.0	10.4	0.27
Average Number of Days Worn	6.9	0.1	6.8	0.2	6.9	0.1	0.28

*gender differences

Table 11A. Domain prevalence and activity prevalence during light intensity physical activity in older adults using the physical activity diary

	Physical Activity Diary						
	Total Sample (N=10661)		Male (n=3111)		Female (n=7550)		
	%	95% CI	%	95% CI	%	95% CI	p-value*
Household	35.2	(34.3-36.1)	29.3	(27.7-30.9)	37.7	(36.7-38.8)	0.52
House Office Work	2.5	(2.0-3.0)	1.1	(0.4-1.8)	2.9	(2.4-3.4)	0.57
Cleaning	15.5	(14.34-16.66)	3.7	(2.5-4.9)	19.2	(18.0-20.5)	0.01
Cooking	23.1	(21.8-24.5)	26.0	(23.2-28.9)	22.2	(20.9-23.5)	0.33
Dishes	3.0	(2.5-3.6)	·		4	(3.4-4.6)	0.81
Gardening	8.4	(7.5-9.3)	12.0	(9.9-14.1)	7.2	(6.4-8.0)	0.97
Household - General	14.9	(13.8-16.0)	20.6	(17.9-23.2)	13.1	(20.0-14.2)	0.92
Laundry	4.9	(4.2-5.6)	2.0	(1.1-2.9)	6.5	(5.7-7.3)	0.39
Pet Care	2.7	(2.2-3.2)	3.3	(2.1-4.5)	2.9	(2.4-3.4)	0.19
Preparing for Bed	2.9	(2.4-3.4)	14.2	(11.9-16.5)	2.6	(2.1-3.1)	0.51
Personal Care	13.8	(12.7-14.9)	0.5	(0.04-1.0)	13.6	(12.5-14.7)	0.33
Yard Work	8.3	(7.4-9.2)	16.6	(14.2-19.0)	5.7	(4.9-6.4)	0.03
Occupation	3.3	(2.9-6.4)	1.4	(1.0-1.8)	4.2	(3.8-4.7)	0.70
Seated Work	30.3	(25.5-35.1)	20.9	(8.75-33.05)	23.6	(19.0-28.3)	0.62
Standing Work	66.7	(61.8-71.6)	79.1	(66.9-33.05)	72.9	(68.0-77.8)	0.68
Phone	3.1	(1.3-4.9)	·		3.5	(1.5-5.5)	0.53
Transportation	12.2	(11.9-12.8)	16.2	(14.9-17.5)	10.5	(9.8-11.2)	0.82
Walking	99.2	(98.7-99.7)	100.0		98.6	(97.8-99.4)	0.11
Biking	0.8	(0.3-1.3)	·		1.4	(0.6-2.2)	0.53
Leisure Time	47.5	(46.6-48.5)	51.7	(49.9-53.5)	45.7	(44.6-46.8)	0.22
Art	1.3	(1.0-1.6)	1.1	(0.6-1.6)	1.4	(1.0-1.8)	0.60
Biking	1.0	(0.7-1.3)	·		1.5	(1.1-1.9)	0.53
Church	0.7	(0.5-0.9)	·		1	(0.7-1.3)	0.43
Computer, Multi-tasking	11.8	(10.9-12.7)	13.6	(11.9-15.3)	11	(10.0-12.0)	0.65
Dancing	2.8	(2.4-3.3)	4.0	(3.0-4.9)	8.6	(7.7-9.5)	0.42
Eating	9.5	(8.7-10.3)	11.4	(9.9-13.0)	7.8	(6.9-8.7)	0.93
Exercise	7.9	(7.2-8.6)	8.2	(6.9-9.5)	1.7	(1.3-2.1)	0.58
Games	1.2	(0.9-1.5)	0.2	(-0.02-0.4)	3.5	(2.9-4.1)	0.95
Grandkids - Playing	3.2	(39.6-42.3)	2.4	(1.7-3.2)	5	(4.3-5.7)	0.18
Knitting/Sewing	3.4	(2.9-3.9)	·		5.2	(4.5-5.9)	0.46
Meeting/Class	4.8	(4.2-5.4)	3.9	(3.0-4.9)	0.4	(0.2-0.6)	0.50
Musical Intruments	0.3	(0.2-0.5)	·		1.9	(1.4-2.5)	0.38
Outside - General	2.2	(1.8-2.6)	2.8	(2.0-3.6)	1.1	(0.8-1.5)	0.61
Phone	0.7	(0.5-0.9)	·		1.1	(0.8-1.5)	0.28
Reading, Multi-tasking	7.2	(6.5-7.9)	6.2	(5.0-7.4)	7.7	(6.8-8.6)	0.92
Shopping	12.0	(11.1-12.9)	11.0	(9.5-12.5)	12.4	(11.3-13.5)	0.76
Sitting	0.1	(0.01-0.2)	·		0.1	(-0.01-0.21)	0.53
Socializing	4.2	(3.7-4.8)	4.8	(3.8-5.8)	4	(3.4-4.7)	0.38
TV, Multi-tasking	17.6	(6.6-18.7)	15.9	(14.1-17.7)	18.4	(17.1-19.7)	0.65
Walking	6.6	(5.9-7.3)	10.1	(8.6-11.6)	5	(4.3-5.7)	0.16

Percentages in categories may not add up to 100%; Unaccounted for percentage annotated as "unknown" time not included in table

*Gender differences

Table 11B. Domain prevalence and activity prevalence during light intensity physical activity in older adults using the wearable camera

	Total Sample (N=2895)		Wearable Camera Male (n=1351)		Female (n=1544)		
	%	95% CI	%	95% CI	%	95% CI	p-value*
Household	34.8	(33.1-36.5)	30.1	(27.6-32.6)	38.9	(36.5-41.3)	0.64
House Office Work	3.3	(2.2-4.4)	3.4	(1.6-5.2)	3.2	(1.8-4.6)	0.40
Cleaning	3.1	(2.1-4.1)	2.5	(1.0-4.0)	3.5	(2.0-4.9)	0.32
Cooking	19.5	(17.2-21.8)	23.6	(19.5-27.7)	16.8	(13.8-19.8)	0.33
Dishes	2.4	(1.5-3.3)	·		4.0	(2.4-5.8)	0.40
Gardening	·		·		·		
Household - General	54.5	(51.5-57.5)	62.4	(57.7-67.1)	49.1	(45.1-53.1)	0.04
Laundry	2.1	(1.3-2.9)	·		3.5	(2.0-4.9)	0.10
Pet Care	2.6	(1.7-3.6)	·		4.3	(2.7-5.9)	0.34
Preparing for Bed	·		·		·		
Personal Care	9.3	(7.6-11.0)	6.4	(4.0-8.8)	11.3	(8.8-13.8)	0.53
Yard Work	2.6	(1.7-3.6)	·		4.3	(2.7-5.9)	0.61
Occupation	2.3	(1.8-2.9)	5.0	(3.8-6.2)	·		0.61
Seated Work	11.9	(4.2-19.6)	11.9	(4.2-19.7)	·		0.61
Standing Work	88.1	(80.4-95.9)	88.1	(80.4-95.9)	·		0.61
Phone							
Transportation	5.3	(4.5-6.1)	5.5	(4.3-6.7)	5.2	(4.1-6.3)	0.46
Walking	100.0		100.0		100.0		0.90
Biking	·		·		·		
Leisure Time	47.3	(45.5-49.1)	40.3	(37.7-42.9)	53.4	(50.9-55.9)	0.24
Art	·		·		·		
Biking	·		·		·		
Church	2.1	(1.3-2.9)	·		3.5	(2.3-4.8)	0.48
Computer, Multi-tasking	6.2	(4.9-7.5)	3.2	(1.7-4.7)	6.2	(4.6-7.9)	0.72
Dancing	·		·		·		
Eating	2.6	(1.8-3.4)	2.2	(1.0-3.4)	2.9	(1.8-4.1)	0.28
Exercise	9.9	(8.3-11.5)	11.9	(9.2-14.6)	8.6	(6.7-10.5)	0.78
Games	·		·		·		
Grandkids - Playing	·		·		·		
Knitting/Sewing	1.5	(0.9-2.1)	·		2.5	(1.4-3.6)	0.61
Meeting/Class	12.4	(10.7-14.2)	15.2	(12.2-18.2)	10.5	(8.4-12.6)	0.35
Musical Intruments	·		·		·		
Outside - General	2.2	(1.4-2.9)	1.1	(0.2-1.9)	2.9	(1.8-4.1)	0.50
Phone	1.4	(0.8-2.0)	2.8	(1.4-4.2)	0.5	(0.02-0.9)	0.54
Reading, Multi-tasking	11.8	(10.1-13.5)	15.4	(12.4-18.4)	9.3	(7.3-11.3)	0.83
Shopping	16.3	(14.3-18.3)	3.3	(1.8-4.8)	24.8	(21.9-27.8)	0.04
Sitting	2.8	(1.9-3.7)	1.1	(0.2-1.9)	4.0	(2.7-5.3)	0.42
Socializing	10.8	(9.2-12.4)	19.1	(15.8-22.4)	5.3	(3.8-6.8)	0.57
TV, Multi-tasking	12.7	(10.9-14.5)	10.1	(7.8-12.6)	14.4	(12.0-16.8)	0.20
Walking	7.2	(5.8-8.6)	11.6	(8.9-14.3)	4.4	(3.0-5.8)	0.90

Percentages in categories may not add up to 100%; Unaccounted for percentage annotated as "unknown" time not included in table

*Gender differences

Table 12A. Location & social interaction during light intensity physical activity using the physical activity diary

	Physical Activity Diary						
	Total Sample (N=10661)		Male (n=3111)		Female (n=7550)		
	%	95% CI	%	95% CI	%	95% CI	p-value*
Location							
Inside	75.9	(75.1-76.7)	65.3	(66.7-69.9)	80.3	(79.3-81.1)	0.01
Outside	21.8	(21.0-22.6)	31.8	(30.2-33.4)	17.7	(16.8-18.6)	0.01
Social Interaction							
No	43.4	(42.5-44.3)	41.1	(39.4-42.8)	44.3	(43.2-45.4)	0.60
Yes	15	(14.3-15.7)	11.9	(10.8-13.0)	16.3	(15.5-17.1)	0.53
Yes - Family	5.3	(4.9-5.7)	4.9	(4.1-5.7)	5.5	(5.0-6.0)	0.57
Yes - Friend(s)	6.4	(5.9-6.8)	10.4	(9.3-11.5)	4.7	(4.2-5.2)	0.25
Yes - Neighbor(s)	3	(2.7-3.3)	4.5	(3.8-5.2)	2.4	(2.1-2.8)	0.91
Yes - Pet(s)	1.8	(1.6-2.1)	0.8	(0.5-1.1)	2.2	(1.9-2.5)	0.28
Yes - Spouse	22.3	(21.5-23.1)	23.4	(21.9-24.9)	21.8	(20.9-22.7)	0.28
Yes - Technology	0.3	(0.2-0.4)	0.3	(0.1-0.5)	0.3	(0.2-0.4)	0.33

Percentages in categories may not add up to 100%; Unaccounted for percentage annotated as "unknown" time not included in table

*Gender differences

Table 12B. Location & social interaction during light intensity physical activity using the wearable camera

	Wearable Camera						
	Total Sample (N=10661)		Male (n=3111)		Female (n=7550)		
	%	95% CI	%	95% CI	%	95% CI	p-value*
Location							
Inside	79.7	(78.2-81.2)	71.5	(69.1-73.9)	86.9	(85.2-88.9)	0.42
Outside	11.3	(10.2-12.5)	9.4	(7.8-11.0)	13	(11.3-14.9)	0.44
Social Interaction							
No	67.7	(66.0-69.4)	58.5	(55.9-61.1)	75.8	(73.7-77.9)	0.84
Yes	22.0	(20.5-23.5)	21.1	(18.9-23.9)	22.8	(20.7-24.9)	0.69
Yes - Family	.		.		.		
Yes - Friend(s)	.		.		.		
Yes - Neighbor(s)	.		.		.		
Yes - Pet(s)	1.3	(0.9-1.7)	1.3	(0.7-1.9)	1.3	(0.7-1.9)	0.30
Yes - Spouse	.		.		.		
Yes - Technology	.		.		.		

Percentages in categories may not add up to 100%; Unaccounted for percentage annotated as "unknown" time not included in table

*Gender differences

Figure 2A. Average time spent in light intensity bouts by time of day measured by hip-worn activity monitor (mean Min/hr) N=45

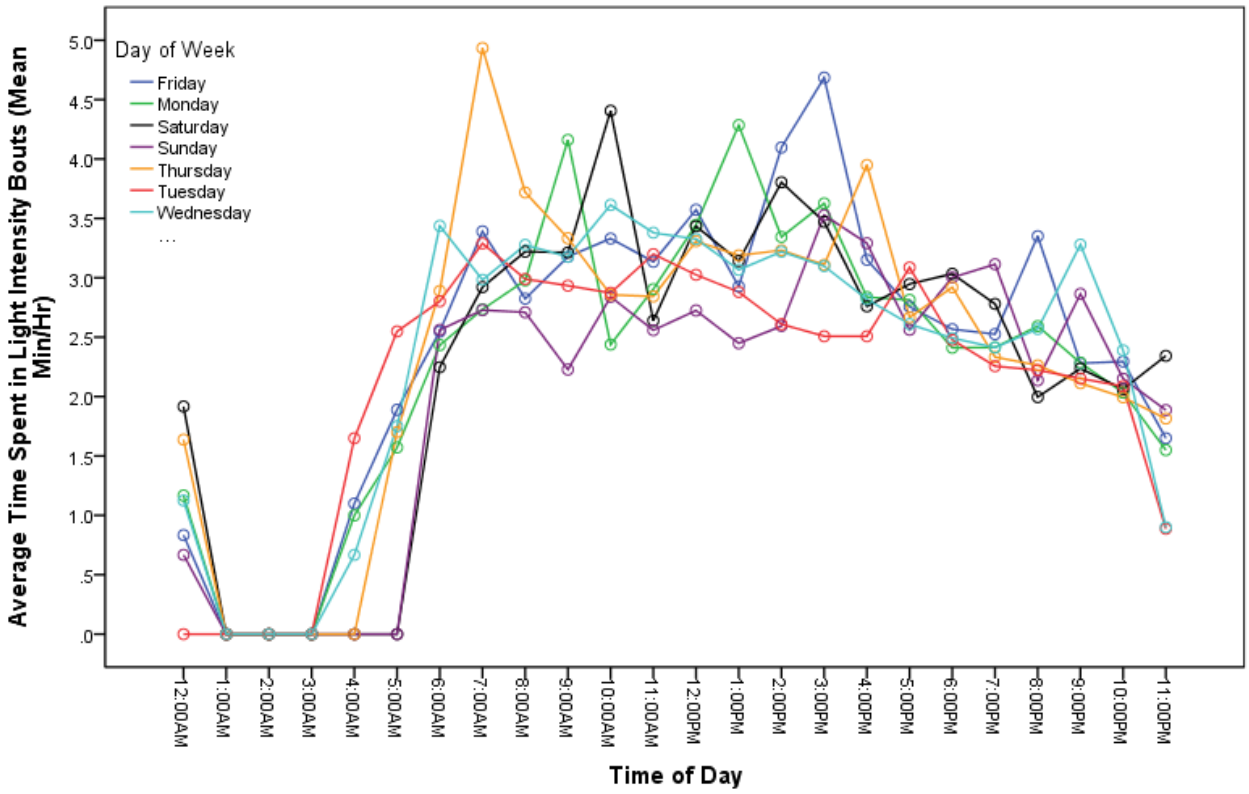


Figure 2B. Number of light intensity bouts by time of day measured by hip-worn activity monitor (mean bouts/hr) N=45

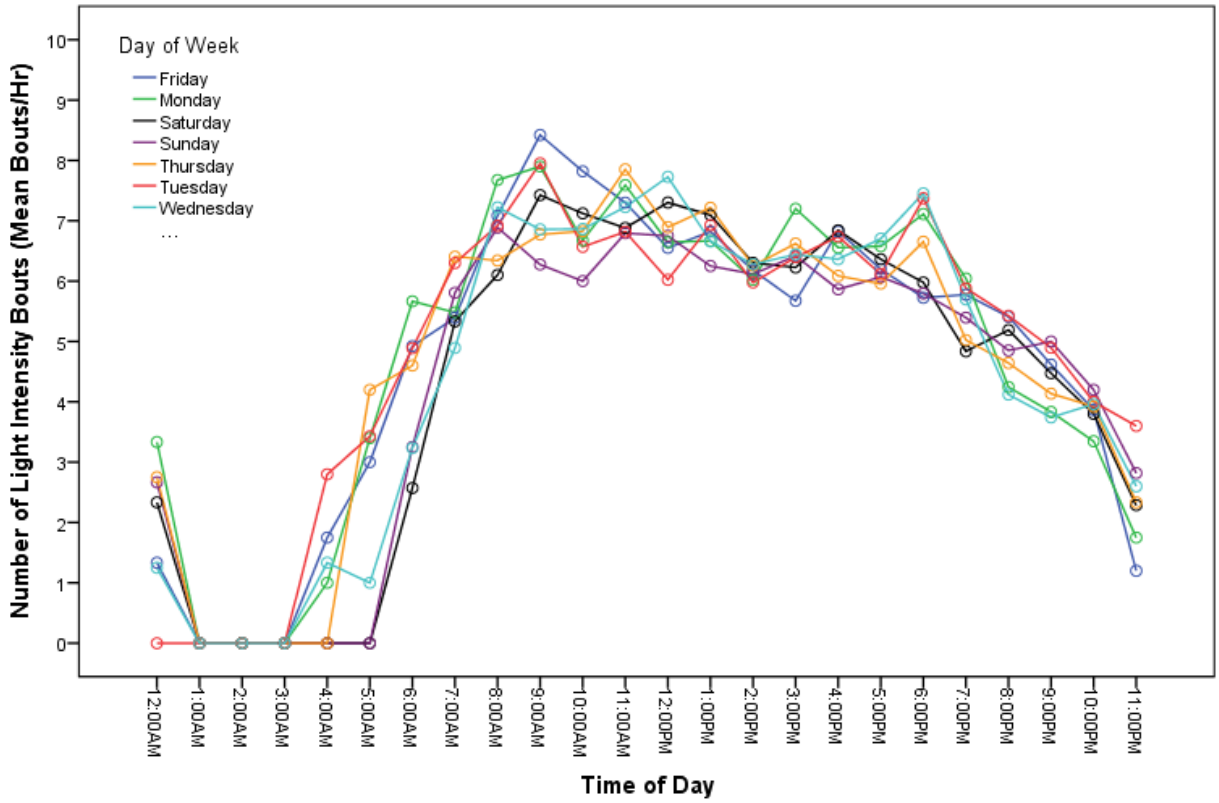


Figure 2C. Average time spent in light intensity bouts by time of day measured by wrist-worn activity monitor (mean Min/hr*)*

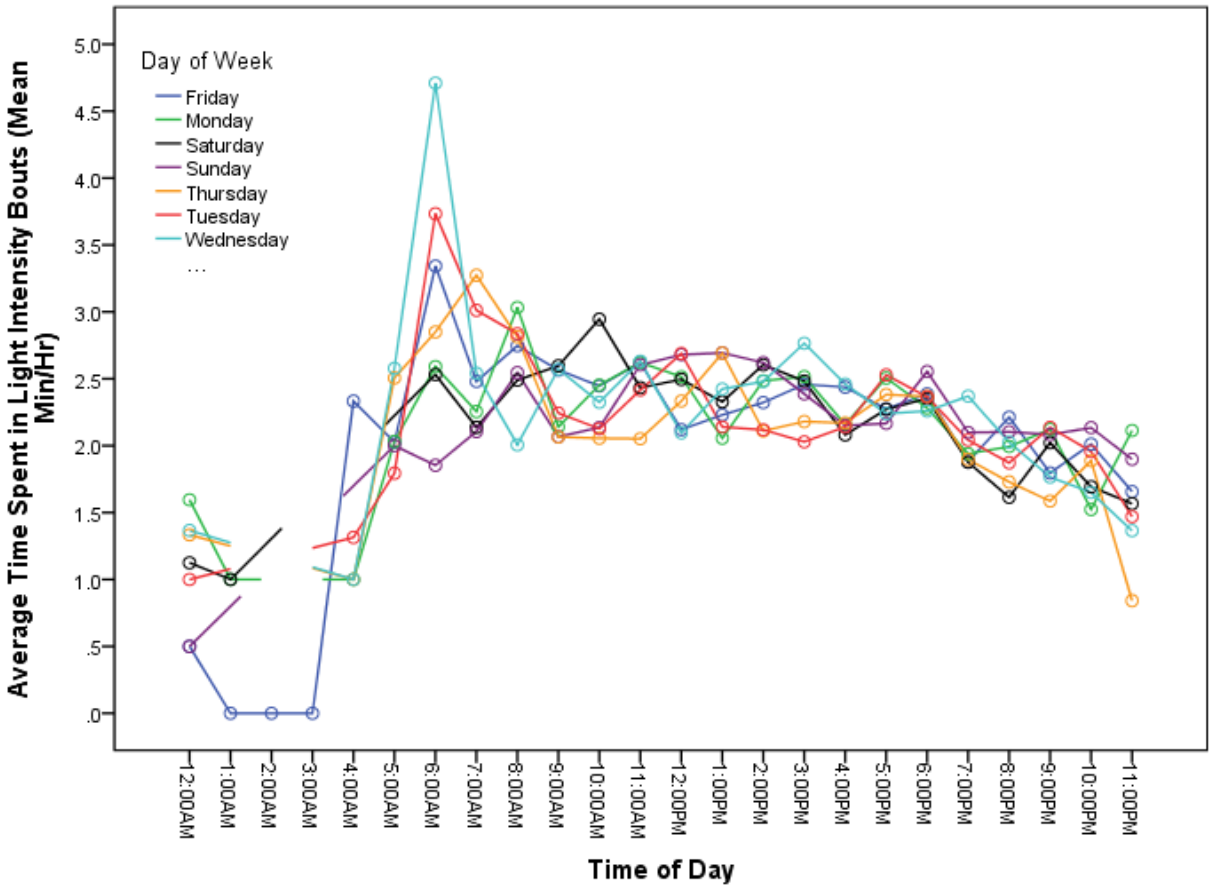


Figure 2D. Number of light intensity bouts by time of day measured by wrist-worn activity monitor (mean bouts/hr) N=45

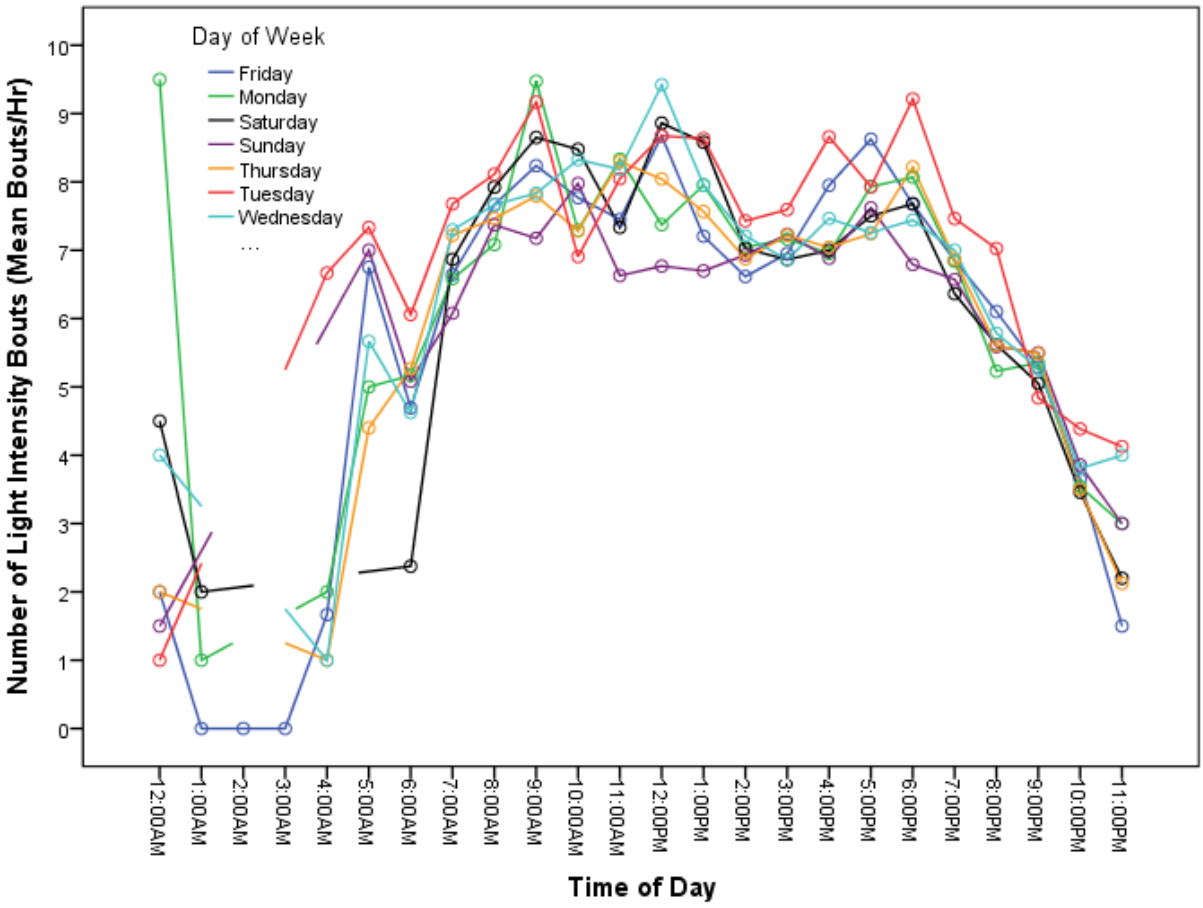


Figure 3A. Average minutes per hour of light intensity physical activity by time of day across days of the week measured by hip-worn activity monitor. N=45

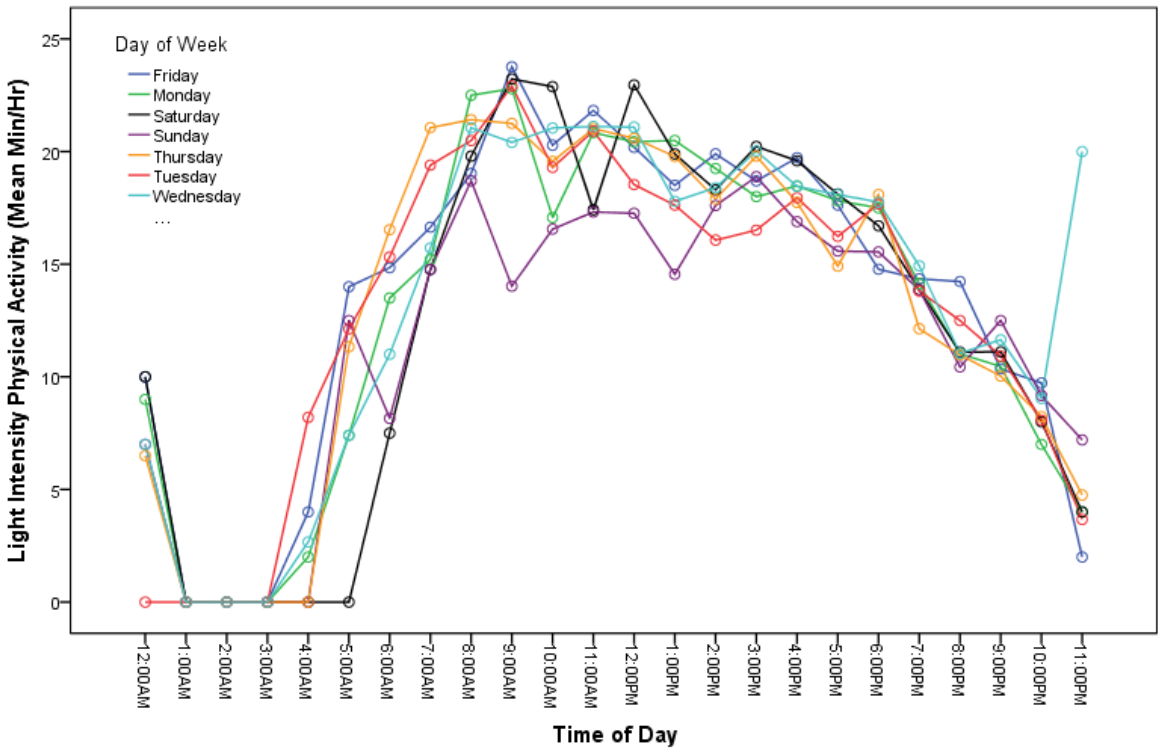
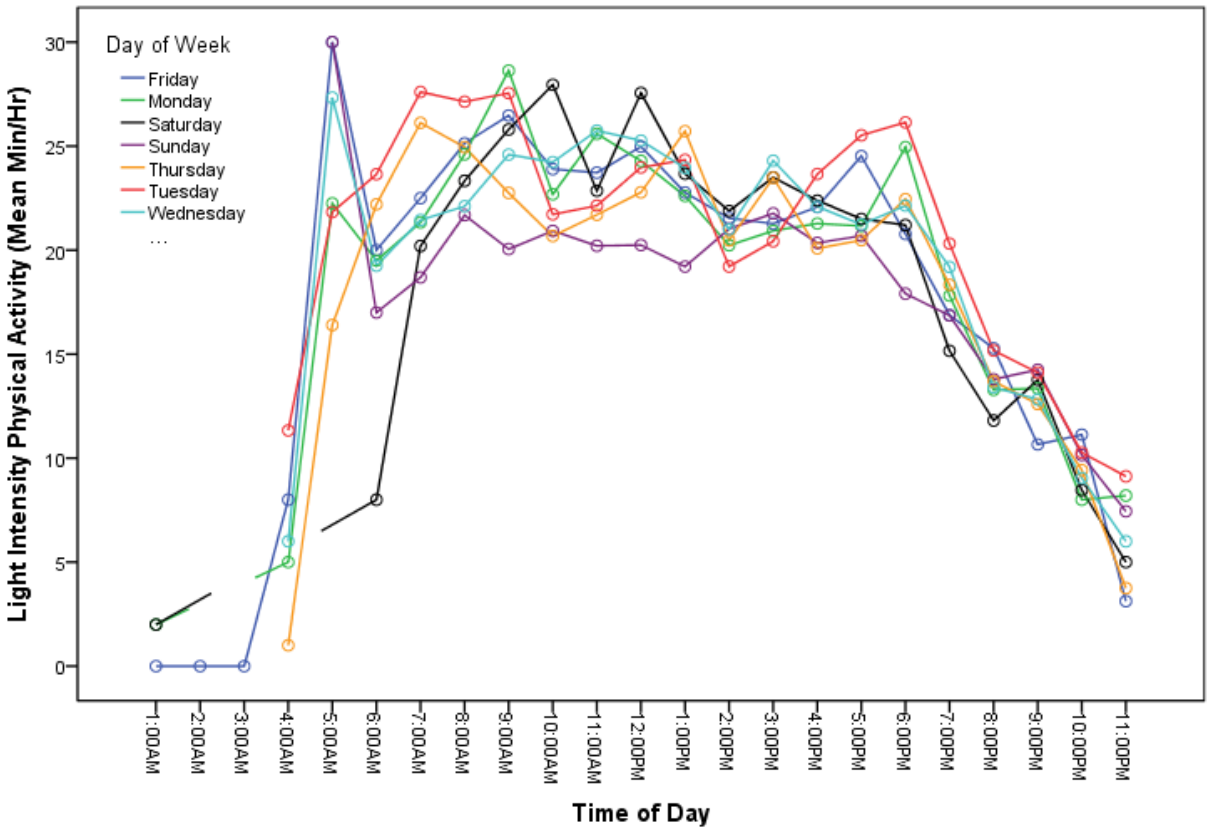


Figure 3B. Average minutes per hours of light intensity physical activity by time of day across days of the week measured by wrist-worn activity monitor. N=45



CHAPTER 5: DOSE-RESPONSE OF LIGHT INTENSITY PHYSICAL ACTIVITY AND GLUCOSE DYNAMICS IN OLDER ADULTS

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Abstract

Purpose: To determine the optimal dose of light intensity physical activity (LPA) for metabolic health by understanding the dose-response effect of proportion of time spent in light intensity physical activity on post-prandial glucose response in older adults in a controlled environment. Methods: Older adults (N=7), 60 y and older, completed a seated, control condition, and three subsequent randomized visits 1) 20% of the condition spent in LPA, the remaining time seated, 2) 40% of the condition spent in LPA, the remaining time seated, and 3) 60% of the condition spent in LPA, the remaining time seated. Each condition lasted for three-hours. Energy expenditure was measured throughout and glucose was measured at baseline of the condition and each hour following ingestion of a mixed meal (Ensure PLUS), up to three hours. Glucose AUC was calculated and compared between conditions. Results: A significantly greater amount of energy was expended during all activity conditions when compared to the seated condition ($p<0.05$). All light intensity activity conditions were significantly different from one another ($p<0.05$) one hour post-load, except between the seated and the 20% LPA condition ($p=0.894$). There was a significant difference between proportions of time spent in LPA and glucose AUC ($F=8.217$, $p=0.001$). Post-hoc analysis showed a significant difference between the seated condition and 40% LPA condition (AUC mean difference: 26.7 mg/dL, $p=0.042$), seated condition and 60% LPA condition (AUC mean difference: 36.8 mg/dL, $p=0.012$), 20% LPA condition and 60% LPA condition (AUC mean difference: 17.6 mg/dL, $p=0.011$), and 40% LPA condition and 60% LPA condition (AUC mean difference: 10.1 mg/dL, $p=0.010$) Conclusion: This study

showed there is a dose-response relationship between time spent in LPA and post-load glucose response in older adults. Currently, LPA constitutes about 30% of the active day, therefore, these results translate to increasing LPA in older adults by 10% per day. This provides experimental evidence to the importance LPA may play in the overall metabolic health of an older adult population.

Introduction

The United States and other industrialized countries are undergoing an inactivity epidemic (75). High levels of sedentary behavior paired with low levels of health-enhancing moderate-to-vigorous intensity physical activities are negatively impacting the health of our nation (86). Until recently, researchers and clinicians have largely ignored light intensity physical activity (LPA) (the activity intensity between sedentary and moderate- to- vigorous) and any benefit to metabolic health. However, when examining temporal patterns of daily activity, studies have shown that the majority of daily active time is spent performing activities that are of a light intensity level. Therefore, researchers have begun to elucidate the importance of LPA to our total daily energy expenditure and provide evidence for the beneficial health effects of low intensity movements (27, 37, 94).

Much of our experimental understanding of the health benefits of LPA is derived from sedentary behavior research. While little experimental research examining the deleterious health effects of sedentary behavior has been performed, research in adults has shown breaks from sedentary behavior are beneficial for glucose regulation (7, 35). These proposed breaks are generally accomplished by introducing some type of light intensity physical activity such as standing or slow walking, they range in duration from two to five minutes in length, and are frequently occurring; usually one break every 20 minutes (7, 35). While these sedentary behavior focused studies have provided valuable evidence for the role LPA may play in post-prandial glucose regulation, this prescription was developed with the intention of breaking up sedentary behavior. There is still much

information that is not known regarding the metabolic benefits of varying levels of LPA and the amount of LPA necessary to obtain these benefits. Understanding the health effects of LPA, which provides a more feasible alternative to accumulating activity when compared to higher intensities, could aid in decreasing the inactivity epidemic across our nation and therefore aid in increasing the overall health status and ultimately the quality of life for older adults. What is still unknown is the optimal dose of light intensity physical activity for glucose response in an older adult population. Therefore, the purpose of this study was to determine this optimal dose of LPA for metabolic health by understanding the dose-response effect of proportion of time spent in light intensity physical activity on glucose response in older adults in a controlled environment. We hypothesized glucose area under the curve will progressively decrease as time spent in LPA increases.

Methods

Participants. Participants were recruited from Milwaukee and the surrounding community, including local senior centers, older adult programs, senior residential communities, campus resources, word of mouth, announcements, and flyers. Inclusion criteria consisted of men or women 60 years of age and older, overweight or obese defined as a body mass index equal to or greater than 25 $kg \cdot m^{-2}$, and inactive, defined by asking participants if they accumulate less then 150 minutes per week of moderate or vigorous physical activity. Participants were excluded from the study if they were not able to ambulate without assistance, had any other limitations to walking on a treadmill, weighed over 300 pounds (based on

equipment specifications), diagnosed with diabetes or were taking any glucose lowering medications, or had any major signs and symptoms of cardiovascular disease (dyspnea, dizziness, tightness or pain in chest, or unusual fatigue at rest or with light exertion) (Appendix L).

Overview. The study design was a single subject, alternating treatment design with a randomized treatment order. Participants completed four visits to the Physical Activity and Health Research Laboratory. Participants reported to the laboratory having refrained from eating or consuming caffeine or any other stimulants for 4 hours or any exercise for the past 24 hours. During their first visit, participants provided verbal and written consent by reviewing and signing an informed consent approved by the university Institutional Review Board (Appendix M). They then completed a health history questionnaire (Appendix N) and had their height and weight measured following standard procedures (108). During the first visit, all participants completed the seated control condition where participants remained seated for three continuous hours. At the end of the three-hour period, participants underwent a treadmill walk test to determine the treadmill speed to be used during the activity conditions in order to verify a light intensity was reached and not surpassed. During the treadmill walk test, participants walked on a treadmill for a total of 15 minutes. Speed was gradually increased every five minutes, starting at 1 mph, and increasing to 1.5, and 2 mph. During the treadmill walk test, energy expenditure was measured using a portable metabolic system. Finally, participants completed a body composition measurement at the end of their first visit to determine percent lean body mass.

Participants then visited the laboratory on three subsequent occasions, completing one of three activity trial conditions at each visit. In between each visit participants were asked to maintain their normal routines in order to adequately capture the effectiveness of the experimental conditions. At all visits, physical activity and diet surveys were completed to monitor consistencies or changes in activity levels and dietary intake throughout the testing weeks.

Intervention: Light Intensity Activity Conditions. The three activity-related conditions were three hours in length, but varied by percent of time spent in light intensity physical activity over the three-hour measurement period. The three conditions included a 20% (36 minutes), 40% (72 minutes), and 60% (108 minutes) light intensity activity routine consisting of treadmill walking, household, occupational, and leisure-time activities, at the beginning of the visit followed by sitting for the remainder of the visit (Table 13). Activity conditions were designed to elicit a dose-response effect of post-prandial glucose, if one existed. Additionally, the percentage of time for each condition were set based on the average light intensity physical activity accumulated each day in the American population (~30%) (115).

The physical activity conditions (2 through 4 above) were randomly ordered. At least a 72-hour washout period occurred between visits due to the effect of physical activity on insulin sensitivity (~72 hours, (109)) to eliminate any previous physical activity effect.

Measures.

Energy Expenditure. Energy expenditure was measured by a portable metabolic measurement system (Cosmed K4b^2, Cosmed Corp, Rome, Italy) throughout each three-hour condition. The Cosmed K4b^2 is a portable metabolic system and battery pack that can be worn by a participant on a harness secured to their trunk. The portable unit is a small (170x55x100 mm) and lightweight (400g) device that secures onto the individuals chest, while the small battery (120x20x80 mm) is placed on the upper back. Oxygen and carbon dioxide are sampled from the facemask covering the participant's nose and mouth and a turbine attached to the facemask measuring ventilation. Breath-by-breath data was averaged into one-minute averages. The Cosmed K4b^2 has shown to be a valid measure of oxygen uptake during exercise and rest (106, 141). The Cosmed K4b2 showed small differences in VO_2, ranging 0.088-0.092 L/min, when compared to the Douglas bag method.

Mixed Meal Tolerance Test. In order to measure the post-prandial effect of LPA, prior to beginning each three-hour measurement participants were asked to consume a standard mixed meal drink (Ensure PLUS, 8 fl oz) (100). The drink had 350 total kcals, consisting of 51g carbohydrates (57%), 11g fat (28%), and 13g protein (15%). Participants were instructed to complete ingestion within five minutes. The activity condition time began once the mixed meal drink was completely consumed.

Glucose Measurement. A capillary blood sample was obtained from the lateral side of the participant's finger, each hour, throughout the three-hour condition measurement period (total of four samples) (Figure 4). As the figure indicates, the

baseline sample was taken prior to the start of the condition and prior to ingestion of the mixed meal. Samples two through four were each taken one-hour apart. Three capillary tubes were filled for a total sample of 150 µL. Blood samples were immediately transferred to tubes containing an anticoagulant. Whole blood glucose was measured by the YSI 2300 STAT Plus glucose analyzer. This analyzer uses 25 µL of whole blood for each measurement. This method of glucose assessment has been shown to provide valid and reliable measurement of glucose concentration (5, 42). Area under the curve (AUC) was then calculated from the baseline and hourly glucose samples using the trapezoid method (143). Glucose values are reported as whole blood values.

International Physical Activity Questionnaire. At each visit participants filled out the International Physical Activity Questionnaire (IPAQ) (Appendix K), which asks questions about the moderate-to-vigorous activity the participant has engaged in over the previous 7 days (2). This information was analyzed using standard procedures. The results of the questionnaire provided information of whether the participants maintained or changed their usual activity levels over the experimental period. The IPAQ has shown good concurrent validity for total physical activity (ρ=0.55) when compared to an activity monitor and log book (47).

Activity Monitor. Participants were asked to wear an activity monitor (Actigraph GT3X+, Actigraph Corp., Pensacola, FL) during all waking hours for seven consecutive days (Appendix O). This measurement period took place following the first laboratory visit. This small, matchbox sized monitor was worn on a belt around the waist, on their right side, in line with the middle of the thigh. Data was collected

at 100 Hz and analyzed in 60-second epochs. Data was processed using standard wear procedures and Troiano cutpoints were used to reduce the data to time spent in sedentary, light, moderate, and vigorous intensity (26, 134).

Automated Self-Administered 24-hour Dietary Recall. At each visit participants completed a computer-based 24-hour recall. The recall questionnaire prompted the participants to report all the food and drink consumed over the past 24-hours. The automated self-administered 24-hour dietary recall has been shown to be valid at assessing dietary intake, showing 80% agreement between recalled intake and true food intake (71). This information was used to test for change in diet prior to each visit.

Body Composition. Total body three compartment body composition was measured using dual-energy x-ray absorptiometry to determine total body fat and fat-free mass (GE Lunar Prodigy, Madison, WI). Dual energy x-ray absorptiometry has been shown to be a valid and reliable measurement of body composition (91).

Statistical Analyses. All statistical analyses were done using SPSS (IBM, Chicago, IL). Descriptive statistics were used to describe the study population. A repeated measures analysis of variance was used to test the main purpose of the study, which was to compare glucose area under the curve response from the four proposed conditions. Observed power achieved was 0.973 with N=7, given a 4-condition, repeated measures analysis of variance analysis. Additionally, repeated measures analysis of variance was used to determine if there were differences in total weekly physical activity (measured by the IPAQ) and nutritional intake (measured by the ASA24) prior to each data collection period.

Results

Seven men (n=3) and women (n=4) completed all study conditions, with full data. Participants were (mean±SE) 71.1±1.5 y, 27.5±5.4 $kg \cdot m^{-2}$ body mass index, and had a lean body mass percent of 70.1±3.0% (Table 14). All participants were white and all were highly educated. Participants' physical activity at baseline showed 250±36 min of light intensity activity per day, 27±7 min of moderate intensity activity per day, 2±2 min of vigorous intensity activity per day and 1824.9±255.9 kcals per day. There were no significant differences in physical activity ($p=0.630$) or dietary intake ($p=0.862$) between each laboratory visit.

Figure 5 shows the change in post-prandial glucose over the 3-hour test time, across each activity condition. As Figure 5 depicts, the greatest peak glucose excursion occurred during the seated condition. At one-hour post-load, results revealed a significant difference in glucose values by activity condition. All light intensity activity conditions were significantly different from one another ($p<0.05$), except between the seated and the 20% LPA condition ($p=0.894$). At two-hour and three-hours post-load, there was no significant difference in glucose values between activity conditions.

Similarly, Figure 6 illustrates the measured energy expenditure (kcal/hr) for each hour during each activity condition. Total energy expenditure for each condition was also calculated. As designed, results indicate a significantly greater amount of energy was expended during all activity conditions when compared to the seated condition ($p<0.05$). Additionally, there is a significant difference between

total energy expended in the 20% LPA condition (263.3±16.1 kcal/hr) and the 40% LPA condition (357.1±24.4 kcal/hr) (p=0.004); no other activity conditions were statistically different.

The overall repeated measures analysis of variance revealed a significant difference between proportions of time spent in LPA and glucose AUC (F=8.217, p=0.001). Post-hoc analysis revealed a significant difference between the seated condition and 40% LPA condition (AUC mean difference: 26.7 mg/dL, p=0.042), seated condition and 60% LPA condition (AUC mean difference: 36.8 mg/dL, p=0.012), 20% LPA condition and 60% LPA condition (AUC mean difference: 17.6 mg/dL, p=0.011), and 40% LPA condition and 60% LPA condition (AUC mean difference: 10.1 mg/dL, p=0.010) (Figure 7).

Discussion

To date, little to no research has experimentally examined the effect of LPA on post-prandial glucose response in older adults. LPA could provide an important means to increasing the physical activity levels in older adults, given it may present a more acceptable and less intimidating activity option. No study has sought to experimentally determine whether there is a dose-response relationship to time spent in LPA and post-prandial glucose response in older adults in order to begin to understand LPA physical activity prescription for metabolic health.

Our results indicate the introduction of light intensity physical activities significantly reduced peak post-prandial glucose excursion in older adults. Additionally, there was a significant effect of activity condition on glucose AUC.

These results suggest the addition of LPA may help improve glycemic control in older adults. Our results are in parallel with previous research examining light intensity breaks from sedentary behavior. Bailey and colleagues compared the effect of a seated condition and seated condition with 2-min light intensity walking breaks (about 2.0 mph) every 20 min on post-prandial glucose changes over a 5-hour period (7). The LPA stimulus resulted in a significant 17% decrease in peak glucose excursion at one-hour post-load, when compared to the seated condition. Our stimulus displayed a 7%, 12%, and 15% decrease in peak glucose excursion in the 20%, 40%, and 60% LPA conditions, respectively. Bailey and colleagues' participants were young adults (24.0±3.0y) with a slightly lower body mass index (26.5±4.3 $kg \cdot m^{-2}$), which may account for the slight differences in percent response, however, both studies saw a similar significant reduction in post-prandial peak glucose response.

We also inquired whether there was a dose-response relationship between time spent in LPA and glucose AUC to identify the optimal amount of LPA required to elicit a beneficial response in glucose AUC. Results revealed a significant difference in glucose AUC by percent of time spent in LPA. More specifically spending 60% of time in LPA had the greatest effect on decreasing post-prandial glucose AUC (12% decrease), significantly different than all other experimental conditions. To our knowledge, no other studies have examined gradations of time spent in LPA and it's effect on glucose, however, previous work has compared glucose AUC between a fully seated activity condition and a seated condition with small bouts of LPA throughout the time period (7). Bailey and colleagues found a

16.7% decrease in glucose AUC between a seated condition and two minutes of light intensity walking every 20 minutes over a five-hour measurement period. Similarly, Dunstan et al. saw a 24.1% decrease in glucose AUC with two minutes light intensity walking breaks every 20 minutes when compared to a seated condition over a five hour testing period (35). Evident from the above findings, LPA shows benefit to decreasing glucose AUC when compared to sitting. What is consistently dissimilar between the current study and previous work is the duration of the activity bout, ours a single, continuous bout, the others short, frequent bouts. Both study designs concluded LPA, whether obtained in bouts or continuously, is a viable option for reducing post-prandial glucose AUC. Future research should continue to examine this notion of bouted LPA versus continuous LPA to better understand the effect of LPA on post-prandial glucose AUC, which would help to frame any potential future LPA prescription.

As discussed, previous research has shown decreased glucose AUC when LPA was completed versus no LPA. These studies however, were designed with the interest in breaking up sedentary behavior, therefore, a novel finding of the current study is beginning to understand the dose-response relationship between post-prandial glucose AUC and LPA. Our results indicate a significant lowering begins to present itself with 40% of the time spent in LPA, with a further significant decrease occurring with each addition of time spent in LPA. These are critical findings considering current PA national estimates report about 30% of the United States population day is spent in LPA. Our results suggest there is evidence for the

promotion of increasing LPA in older adults even by 10% to see an enhancement to metabolic health.

The notion that increasing physical activity would benefit post-prandial glucose control is not a new idea. A review by Kelley and Goodpaster reports the therapeutic and preventative effects of physical activity for individuals with diabetes or those who wish to prevent the development of diabetes, emphasizing the importance of contraction-mediated glucose uptake when insulin-mediated uptake is impaired (67). Perhaps one of the most popular examples of this comes from the Diabetes Prevention Program, which showed a 30% decreased risk of type 2 diabetes diagnosis after three years with lifestyle modifications, which included increasing exercise to 150 min per week of moderate intensity activity (72). Few studies have examined whether or not a lower intensity would provide a sufficient stimulus to elicit the contraction-mediated effect similar to that in higher intensities (moderate or vigorous intensity activities). Dunstan et al. compared the effect on glucose AUC of breaking up time spent sitting with either light intensity or moderate intensity walking breaks, 2 min in duration, every 20 min, for 5-hours (35). Results showed there was a significant decrease in glucose AUC for both intensity conditions when compared to the seated condition, however, there was no difference between the two activity conditions (light intensity: 24.1% lower AUC, moderate intensity: 29.6% lower AUC). Although we do not have a direct comparison to moderate activity, our results provide evidence that there is a dose-response relationship for post-prandial glucose between light intensity activity with increasing duration of time, suggesting a lower intensity stimulus may be sufficient.

Strengths of the current study include the measurement of energy expenditure during each activity condition and the inclusion of multiple modes of LPA in the activity conditions since LPA is generally accumulated in a number of ways, not predominantly ambulatory like moderate or vigorous intensity activities. A limitation to the current study was using a three-hour time period to simulate one day, however, energy expenditure measurement with indirect calorimetry limited our measurement time. Future work could expand upon these findings by examining additive or sustained effects of LPA throughout a day. Another limitation to the current study was the use of a laboratory, controlled setting. Our positive findings from the controlled condition indicate future studies in free-living conditions are warranted.

Conclusion

The current study shows there is a dose-response relationship between time spent in LPA and post-load glucose response in older adults. More specifically, results indicated there was a significant decrease in glucose AUC when 40% of the simulated day or greater was spent in LPA. Currently, LPA constitutes about 30% of the active day. Therefore, the translation of these findings to increase LPA in older adults by 10% per day to begin to see health enhancing effects, provides experimental evidence to the importance LPA may play in the overall metabolic health of our older adult population. Future research should continue to refine this relationship between LPA and glucose in addition to applying this model to other populations, such as those with type 2 diabetes.

Table 13. Activity routine for each activity condition. Time spent in minutes for each activity

Activity	Condition 1: 20% time in light intensity	Condition 2: 40% time in light intensity	Condition 3: 60% time in light intensity
Treadmill Walking (min)	4.5	9	13.5
Household: Folding Laundry/Dusting/Sweeping (min/min/min)	1.5/1.5/1.5	3/3/3	4.5/4.5/4.5
Treadmill Walking (min)	4.5	9	13.5
Occupational: Standing Work (min)	4.5	9	13.5
Treadmill Walking (min)	4.5	9	13.5
Leisure Time: Playing Cards/Cycling/Light Calisthenics (min/min/min)	1.5/1.5/1.5	3/3/3	4.5/4.5/4.5
Treadmill Walking (min)	4.5	9	13.5
Seated (min)	144	108	72

Table 14. Participant descriptives at baseline

Table 3. Participant descriptives at baseline (Mean(SE) or %)	
Gender (% male)	42.9%
Age (y)	71.1(1.5)
Race (% white)	100%
Education (%)	
College	57.1%
Graduate School	42.9%
Mass (kg)	73.4(5.4)
Height (cm)	165.1(4.3)
Body Mass Index (kg/m^2)	27.5(0.9)
Lean Mass (%)	70.1(3.0)
Fasting Glucose (mg/dL)	88.4(2.5)
Physical Activity (accelerometer-determined)	
Wear Time (min/d)	827.6(22.4)
Sedentary Time (min/d)	508.3(21.4)
Light Intensity (min/d)	249.6(35.6)
Moderate Intensity (min/d)	26.9(6.9)
Vigorous Intensity (min/d)	2.3(2.3)
Physical Activity (International Physical Activity Questionnaire)	
Met-Min/wk	1645.2(99.6)
Diet (ASA24)	
Total kcals	1824.9(255.9)
Protein (g)	75.7(17.2)
Fat (g)	77.5(8.6)
Carbohydrates (g)	196.5(32.6)

Figure 4. Blood sample timing (sample time represented by each arrow)

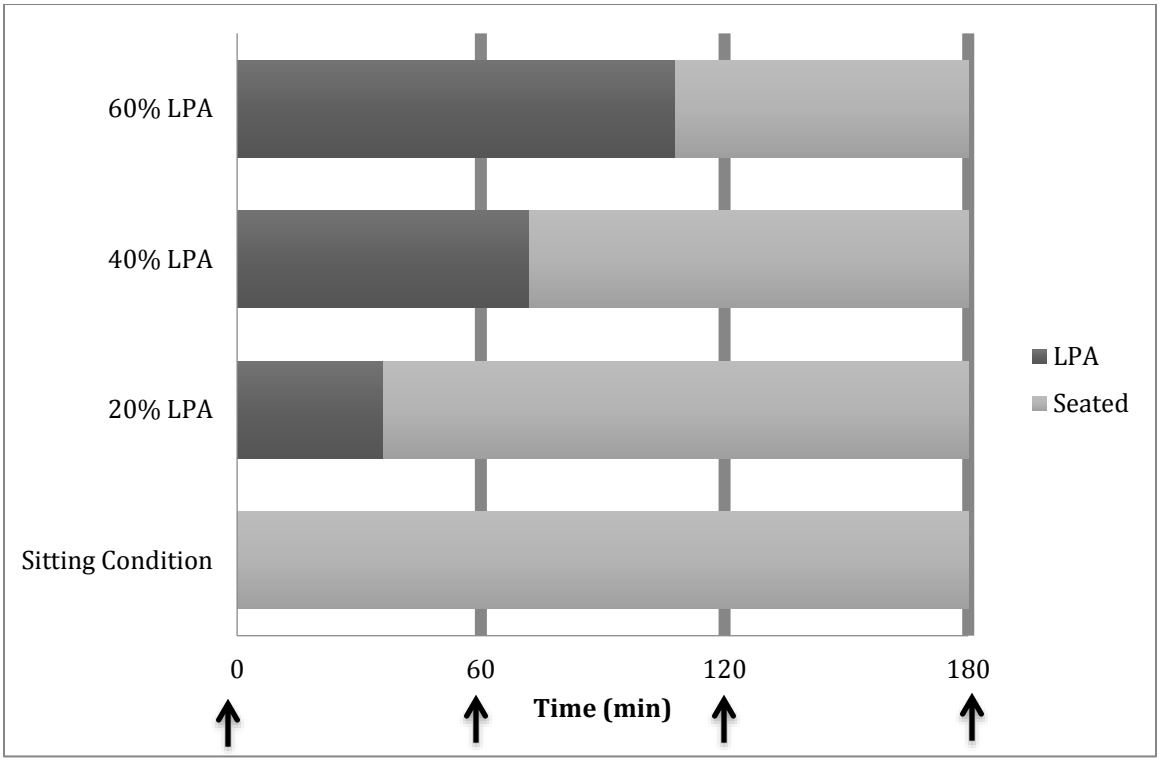


Figure 5. Post-prandial glucose (mg/dL) (mean and standard error) changes across time by activity condition.

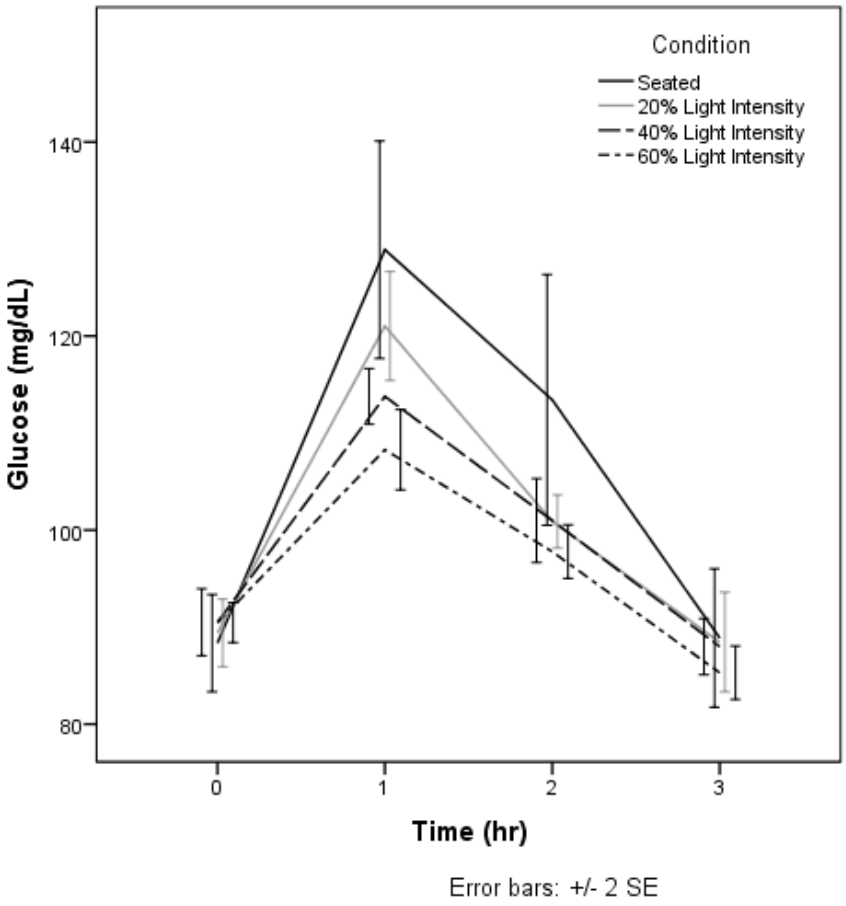


Figure 6. Cumulative hourly energy expenditure by activity condition

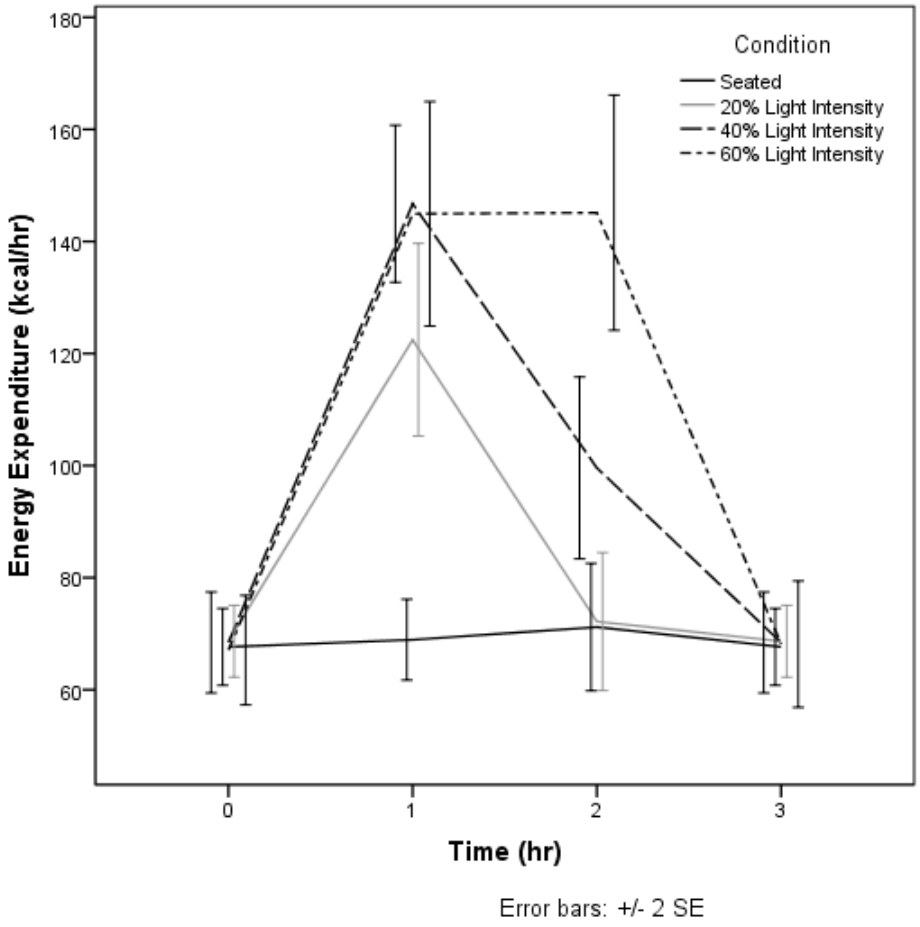
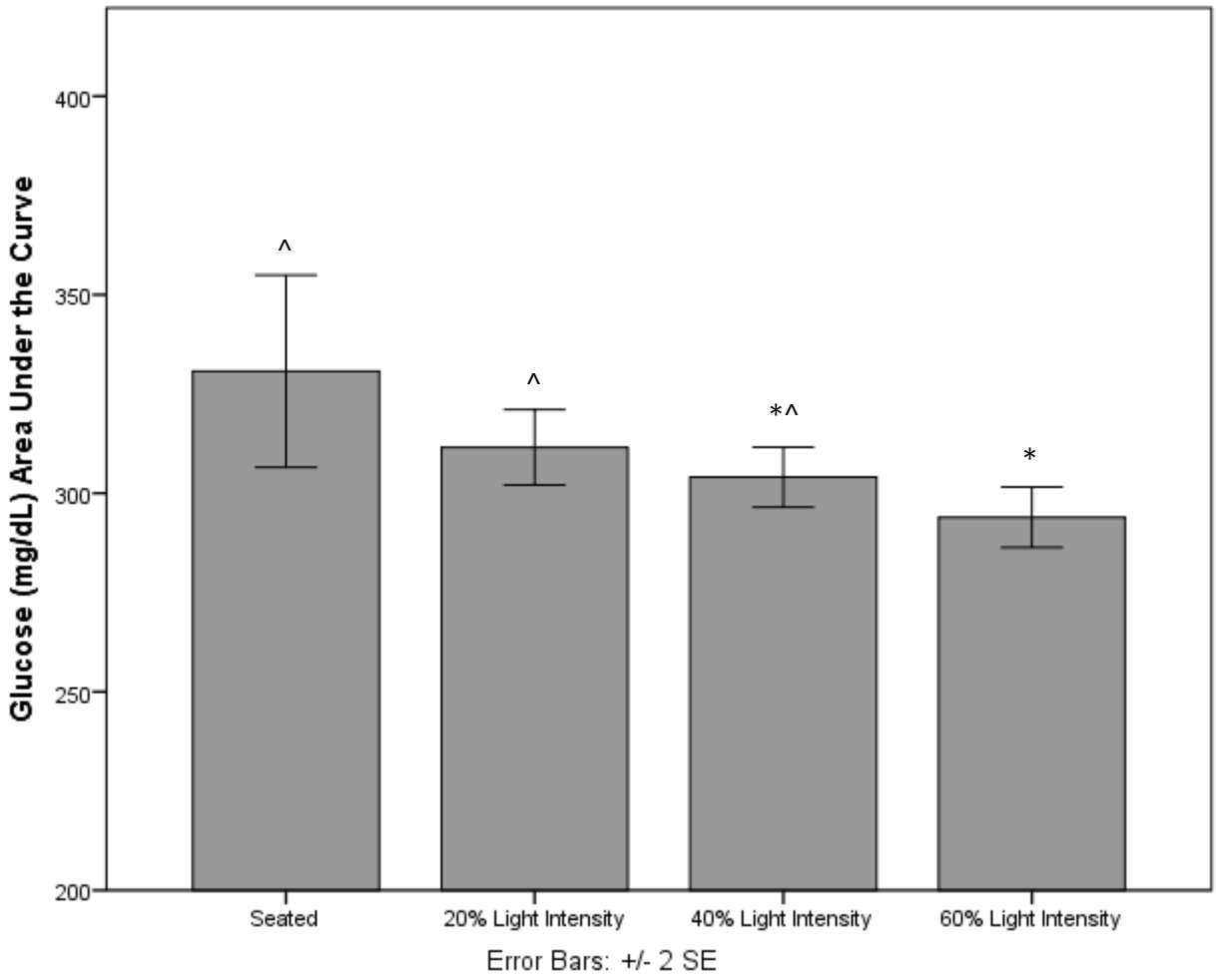


Figure 7. Mean and standard error glucose area under the curve by activity condition



*significantly different than seated condition
^significantly different than 60% light intensity condition

CHAPTER 6: SUMMARY & CONCLUSION

In 2008, the U.S. Department of Health and Human Services released their updated Physical Activity Guidelines for Americans (137). Similar to previous years, these guidelines recommended adults or older adults to participate in moderate intensity activity, vigorous intensity activity, or a combination of the two. In recent years much has been revealed on the damaging effects of prolonged sedentary behavior, with Australia leading the international charge on this "epidemic" by developing sitting guidelines (53). Evidently missing from guideline development is engagement in light intensity physical activity. While the 2008 report states there is currently insufficient evidence to nationally recommend LPA as a health enhancer, supplementary research has begun to quickly emerge on the potential benefit of LPA to the health of adults and older adults. However, little in specifically known about LPA, and a number of the current LPA research stems from the sedentary behavior research (7, 35, 36). Therefore, the purpose of this dissertation was to more fully understand, describe, and characterize potential health benefits of LPA by determining the prevalence, patterns, and health benefits of light intensity physical activity in older adults. Three individual studies were completed to address each portion of this purpose.

Study 1: Light Intensity Physical Activity and Health in Adults: A Systematic Review

This study sought to critically examine the current literature pertaining to LPA and whether research supported a benefit or lack of benefit to adults. Upon search, five health categories emerged and were examined: 1) all cause mortality, 2) metabolic health, 3) cardiovascular health, 4) cancer risk, and 5) functional health. Overall findings suggested there may be benefit to incorporating LPA within the day in order to decrease risk of all-cause mortality, decrease insulin resistance, c-reactive protein, glucose, insulin, metabolic syndrome, physical function, and increase cognition. Additionally, half of the reviewed conditions yielded insufficient evidence to draw an evidence-based conclusion, suggesting there is much latitude for future research direction. Sixty-one percent of the identified studies examining LPA and health were cross-sectional studies, with interventions only making up 7.7% of the reviewed studies.

This review study has filled the identified knowledge gap by compiling the pertinent literature to LPA and health in adults, however, it also recognized a number of critical holes in the current literature to address for future research such as standardizing the definition and classification of LPA in order to better compare the stimulus used across studies. It was additionally noted the immense modes in which LPA was measured, therefore placing resources towards developing precise measurement tools should be a future priority. As evidenced by over half the reviewed studies were of a cross-sectional design, future studies should design and carry out experimental and long-term interventional studies to confirm the current findings. Finally, researchers should continue to identify which populations may benefit most from these potential future activity recommendations. The results from

this review suggested adults who were inactive, had been diagnosed with a chronic disease, or those who were older, showed a greater benefit to engaging in LPA than those who were healthy and physically active.

Study 2: Contextual Analysis of Physical Activity

The second study was an observational study, designed to ascertain information on the patterns and context of LPA in older adults. Older adults' physical activity was measured over seven days and the context of their LPA was recorded on one day for a simultaneous measurement and objective identification of time spent in LPA. Our results suggested older adults engaged in over 250 min per day of LPA, in mostly short, frequent bouts (~2.5 min each bout). Additionally, of interest, LPA was performed for a consistent 15-25 min each hour from 7am until 7pm. These data extend the current literature by empirically establishing on average, how long LPA bouts occur for and bout disbursement throughout the day. Understanding how these behaviors are already accumulated provides a beginning point for future intervention and experimental work.

When activity domain was examined, over half of the activity occurred during participants' leisure time. Popular specific activities included leisure-time activities such as multi-tasking while watching television or on the computer, shopping, and household activities such as cooking and cleaning. Furthermore, contextual measurement revealed the LPA was more commonly performed inside when the participant was by themselves, as opposed to with a group. This

information is important for designing behavior change interventions to increase LPA in older adults. Understanding what LPA activities are already prevalent and specific to older adults, the social support necessary to elicit the behavior, and the location these activities most commonly occur to help identify potential barriers to the activity prescription (weather, transportation, resources, etc.).

Study 3: Dose response to LPA and glucose dynamics in older adults

The final study was an experimentally-designed study to systematically increase the amount of time spent in LPA, from 0% of the 3-hr measurement period spent active up to 60% of the measurement period spent in activity, and to detect whether these changes in LPA duration would elicit a stair step response in post-prandial glucose. The purpose of this study was to determine whether there was a dose-response relationship between the total amount of time spent in LPA and post-prandial glucose response in older adults. Results from these trials showed there was a significant decrease in glucose area under the curve 3-hours post-meal when 40% of the measured time was spent in LPA. This effect was further compounded when time spent in LPA was increased to 60% of the measurement period. This study was one of the first with an explicit focus on LPA and provides evidence there is a metabolic health benefit to engaging in LPA, that can further increase in benefit with increasing time spent in lower intensity activities.

Collectively, these studies provide evidence that LPA may be a feasible physical activity selection for older adults and these active behaviors, even at low intensities, may be health enhancing. While the review study provides a solid foundation to understand what we already know by what has been published in the literature, study's 2 and 3 build on this idea of LPA and health with a more narrowed focus on LPA. Study 3 answered the question of whether or not LPA would provide a sufficient stimulus to alter glucose uptake and further still whether that response would be dose-dependent. In light of the positive findings from study 3, study 2 becomes even more applicable. If it is determined with our findings and future accumulated evidence that LPA should be considered within the federal recommended physical activity for health guidelines, the results from study 2 would assist health and fitness professionals and researchers in designing and developing appropriate LPA prescriptions. As our results directed, activity data from objectively measured LPA showed LPA activities, therefore prescription development, are not synonymous with moderate and vigorous activities and therefore should be considered individually. Additionally, our results are in contrast to previous research using the compendium of physical activities to identify light intensity activities, whose classification schema led to many overlooked activities, especially those within the leisure-time domain (136).

These outcomes provide an important, positive impact on population health by providing evidence for older adults to be physically active through a potentially more attainable approach in order to gain health benefits. By placing an emphasis on increasing the activity levels of our population, we provide cost-effective

prevention and treatment options for individuals with or at risk for chronic disease. Decreasing the prevalence of these widespread chronic diseases, such as type 2 diabetes, will decrease the economic cost burden on our country and increase the health of older adults with a resultant effect of extending the quality of their remaining years of life.

REFERENCES

1.Aguilar-Farias N, Brown WJ, and Peeters GM. ActiGraph GT3X+ cut-points for identifying sedentary behaviour in older adults in free-living environments. *J Sci Med Sport*. 2014;17(3):293-9.

2.Ainsworth BE, Bassett DR, Jr., Strath SJ, et al. Comparison of three methods for measuring the time spent in physical activity. *Med Sci Sports Exerc*. 2000;32(9 Suppl):S457-64.

3.Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000;32(9 Suppl):S498-504.

4.Association AD. *ADA Evidence Analysis Manual*. Chicago, IL; 2005.

5.Astles JR, Sedor FA, and Toffaletti JG. Evaluation of the YSI 2300 glucose analyzer: algorithm-corrected results are accurate and specific. *Clin Biochem*. 1996;29(1):27-31.

6.Atienza AA, Moser RP, Perna F, et al. Self-reported and objectively measured activity related to biomarkers using NHANES. *Med Sci Sports Exerc*. 2011;43(5):815-21.

7.Bailey DP, and Locke CD. Breaking up prolonged sitting with light-intensity walking improves postprandial glycemia, but breaking up sitting with standing does not. *J Sci Med Sport*. 2014.

8.Balke B. The effect of physical exercise on the metabolic potential, a crucial measure of physical fitness. *Exercise and Fitness*. Illinois: The Athletic Institute; 1960.

9.Banks E, Lim L, Seubsman SA, Bain C, and Sleigh A. Relationship of obesity to physical activity, domestic activities, and sedentary behaviours: cross-sectional findings from a national cohort of over 70,000 Thai adults. *BMC Public Health*. 2011;11:762.

10.Barwais FA, Cuddihy T, Washington T, Tomson ML, and Brymer E. Development and Validation of a New Self-Report Instrument for Measuring Sedentary Behaviors and Light-Intensity Physical Activity in Adults. *J Phys Act Health*. 2013.

11.Barwais FA, Cuddihy TF, and Tomson LM. Physical activity, sedentary behavior and total wellness changes among sedentary adults: a 4-week randomized controlled trial. *Health Qual Life Outcomes*. 2013;11:183.

12.Bassett DR, Jr., Rowlands A, and Trost SG. Calibration and validation of wearable monitors. *Med Sci Sports Exerc*. 2012;44(1 Suppl 1):S32-8.

13.Bassett DR, Jr., Wyatt HR, Thompson H, Peters JC, and Hill JO. Pedometer-measured physical activity and health behaviors in U.S. adults. *Med Sci Sports Exerc*. 2010;42(10):1819-25.

14.Berggren GaCEH. Heart rate and body temperature as indices of metabolic rate during work. *Arbeitsphysiologie*. 1950;14(3):255-60.

15.Blair CK, Morey MC, Desmond RA, et al. Light-intensity activity attenuates functional decline in older cancer survivors. *Med Sci Sports Exerc*. 2014;46(7):1375-83.

16.Blair SN, LaMonte MJ, and Nichaman MZ. The evolution of physical activity recommendations: how much is enough? *Am J Clin Nutr*. 2004;79(5):913S-20S.
17.Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehab Med*. 1970;2(3):92-3.
18.Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14(5):377-81.
19.Brawley LR, Rejeski WJ, and King AC. Promoting physical activity for older adults: the challenges for changing behavior. *Am J Prev Med*. 2003;25(3 Suppl 2):172-83.
20.Brownson RC, Boehmer TK, and Luke DA. Declining rates of physical activity in the United States: what are the contributors? *Annu Rev Public Health*. 2005;26:421-43.
21.Buman MP, Hekler EB, Haskell WL, et al. Objective light-intensity physical activity associations with rated health in older adults. *Am J Epidemiol*. 2010;172(10):1155-65.
22.Calabro M, Lee JM, Saint-Maurice PF, Yoo H, and Welk GJ. Validity of physical activity monitors for assessing lower intensity activity in adults. *Int J Behav Nutr Phys Act*. 2014;11(1):119.
23.Carlson SA, Fulton JE, Pratt M, Yang Z, and Adams EK. Inadequate physical activity and health care expenditures in the United States. *Prog Cardiovasc Dis*. 2015;57(4):315-23.
24.Chastin SF, Ferriolli E, Stephens NA, Fearon KC, and Greig C. Relationship between sedentary behaviour, physical activity, muscle quality and body composition in healthy older adults. *Age Ageing*. 2012;41(1):111-4.
25.Chen KY, and Bassett DR, Jr. The technology of accelerometry-based activity monitors: current and future. *Med Sci Sports Exerc*. 2005;37(11 Suppl):S490-500.
26.Choi L, Ward SC, Schnelle JF, and Buchowski MS. Assessment of wear/nonwear time classification algorithms for triaxial accelerometer. *Med Sci Sports Exerc*. 2012;44(10):2009-16.
27.Colbert LH, Matthews CE, Schoeller DA, Havighurst TC, and Kim K. Intensity of physical activity in the energy expenditure of older adults. *J Aging Phys Act*. 2014;22(4):571-7.
28.Copeland JL, and Esliger DW. Accelerometer assessment of physical activity in active, healthy older adults. *J Aging Phys Act*. 2009;17(1):17-30.
29.Cordain L, Gotshall RW, Eaton SB, and Eaton SB, 3rd. Physical activity, energy expenditure and fitness: an evolutionary perspective. *Int J Sports Med*. 1998;19(5):328-35.
30.Dallal CM, Brinton LA, Matthews CE, et al. Accelerometer-based measures of active and sedentary behavior in relation to breast cancer risk. *Breast Cancer Res Treat*. 2012;134(3):1279-90.
31.Davis MG, and Fox KR. Physical activity patterns assessed by accelerometry in older people. *Eur J Appl Physiol*. 2007;100(5):581-9.
32.Doherty AR, Kelly P, Kerr J, et al. Using wearable cameras to categorise type and context of accelerometer-identified episodes of physical activity. *Int J Behav Nutr Phys Act*. 2013;10:22.
33.Donahoo WT, Levine JA, and Melanson EL. Variability in energy expenditure and its components. *Curr Opin Clin Nutr Metab Care*. 2004;7(6):599-605.

34.Duncan MJ, Birch SL, and Oxford SW. The effect of exercise intensity on postresistance exercise hypotension in trained men. *J Strength Cond Res*. 2014;28(6):1706-13.
35.Dunstan DW, Kingwell BA, Larsen R, et al. Breaking up prolonged sitting reduces postprandial glucose and insulin responses. *Diabetes Care*. 2012;35(5):976-83.
36.Duvivier BM, Schaper NC, Bremers MA, et al. Minimal intensity physical activity (standing and walking) of longer duration improves insulin action and plasma lipids more than shorter periods of moderate to vigorous exercise (cycling) in sedentary subjects when energy expenditure is comparable. *PLoS One*. 2013;8(2):e55542.
37.Ekblom-Bak E, Ekblom B, Vikstrom M, de Faire U, and Hellenius ML. The importance of non-exercise physical activity for cardiovascular health and longevity. *Br J Sports Med*. 2014;48(3):233-8.
38.Evenson KR, Buchner DM, and Morland KB. Objective measurement of physical activity and sedentary behavior among US adults aged 60 years or older. *Prev Chronic Dis*. 2012;9:E26.
39.Evenson KR, Butler EN, and Rosamond WD. Prevalence of physical activity and sedentary behavior among adults with cardiovascular disease in the United States. *J Cardiopulm Rehabil Prev*. 2014;34(6):406-19.
40.Falconer CL, Page AS, Andrews RC, and Cooper AR. The Potential Impact of Displacing Sedentary Time in Adults with Type 2 Diabetes. *Med Sci Sports Exerc*. 2015;47(10):2070-5.
41.Feito Y, Garner HR, and Bassett DR. Evaluation of ActiGraph's Low-Frequency Filter in Lab and Free-living Environments. *Med Sci Sports Exerc*. 2014.
42.Freckmann G, Baumstark A, Jendrike N, et al. System accuracy evaluation of 27 blood glucose monitoring systems according to DIN EN ISO 15197. *Diabetes Technol Ther*. 2010;12(3):221-31.
43.Freedson PS, Melanson E, and Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. *Med Sci Sports Exerc*. 1998;30(5):777-81.
44.Gando Y, Murakami H, Kawakami R, et al. Light-intensity physical activity is associated with insulin resistance in elderly Japanese women independent of moderate-to vigorous-intensity physical activity. *J Phys Act Health*. 2014;11(2):266-71.
45.Gay JL, Kohl HW, 3rd, Salinas JJ, McCormick JB, and Fisher-Hoch SP. Contribution of occupation to high doses of light-intensity activity and cardiovascular risk factors among Mexican American adults. *J Phys Act Health*. 2014;11(7):1342-9.
46.Green AN, McGrath R, Martinez V, Taylor K, Paul DR, and Vella CA. Associations of objectively measured sedentary behavior, light activity, and markers of cardiometabolic health in young women. *Eur J Appl Physiol*. 2014;114(5):907-19.
47.Hagstromer M, Oja P, and Sjostrom M. The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. *Public Health Nutr*. 2006;9(6):755-62.
48.Hall KS, Howe CA, Rana SR, Martin CL, and Morey MC. METs and accelerometry of walking in older adults: standard versus measured energy cost. *Med Sci Sports Exerc*. 2013;45(3):574-82.

49.Harris AM, Lanningham-Foster LM, McCrady SK, and Levine JA. Nonexercise movement in elderly compared with young people. *Am J Physiol Endocrinol Metab*. 2007;292(4):E1207-12.
50.Hart TL, Swartz AM, Cashin SE, and Strath SJ. How many days of monitoring predict physical activity and sedentary behaviour in older adults? *Int J Behav Nutr Phys Act*. 2011;8:62.
51.Haskell WL. J.B. Wolffe Memorial Lecture. Health consequences of physical activity: understanding and challenges regarding dose-response. *Med Sci Sports Exerc*. 1994;26(6):649-60.
52.Hawkins MS, Storti KL, Richardson CR, et al. Objectively measured physical activity of USA adults by sex, age, and racial/ethnic groups: a cross-sectional study. *Int J Behav Nutr Phys Act*. 2009;6:31.
53.Health AGDo. Australia's Physical Activity and Sedentary Behaviour Guidelines for Adults (18-64 years). 2014.
54.Healy GN, Dunstan DW, Salmon J, et al. Objectively measured light-intensity physical activity is independently associated with 2-h plasma glucose. *Diabetes Care*. 2007;30(6):1384-9.
55.Healy GN, Wijndaele K, Dunstan DW, et al. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care*. 2008;31(2):369-71.
56.Healy GN, Winkler EA, Brakenridge CL, Reeves MM, and Eakin EG. Accelerometer-derived sedentary and physical activity time in overweight/obese adults with type 2 diabetes: cross-sectional associations with cardiometabolic biomarkers. *PLoS One*. 2015;10(3):e0119140.
57.Henchoz Y, Bastardot F, Guessous I, et al. Physical activity and energy expenditure in rheumatoid arthritis patients and matched controls. *Rheumatology (Oxford)*. 2012;51(8):1500-7.
58.Hendelman D, Miller K, Baggett C, Debold E, and Freedson P. Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Med Sci Sports Exerc*. 2000;32(9 Suppl):S442-9.
59.Herzig KH, Ahola R, Leppaluoto J, Jokelainen J, Jamsa T, and Keinanen-Kiukaanniemi S. Light physical activity determined by a motion sensor decreases insulin resistance, improves lipid homeostasis and reduces visceral fat in high-risk subjects: PreDiabEx study RCT. *Int J Obes (Lond)*. 2014;38(8):1089-96.
60.Hill JO, Wyatt HR, Reed GW, and Peters JC. Obesity and the environment: where do we go from here? *Science*. 2003;299(5608):853-5.
61.Howard B, Winkler EA, Sethi P, et al. Associations of Low- and High-Intensity Light Activity with Cardiometabolic Biomarkers. *Med Sci Sports Exerc*. 2015.
62.Howley ET. Type of activity: resistance, aerobic and leisure versus occupational physical activity. *Med Sci Sports Exerc*. 2001;33(6 Suppl):S364-9; discussion S419-20.
63.Howley ET, and Franks BD. *Fitness Professional's Handbook*. Champiagn, IL: Human Kinetics; 2007.
64.Janz KF. Use of Heart Rate Monitors to Assess Physical Activity. In: GJ Welk editor. *Physical activity assessment for health-related research*. Human Kinetics; 2002.

65.Jefferis BJ, Sartini C, Lee IM, et al. Adherence to physical activity guidelines in older adults, using objectively measured physical activity in a population-based study. *BMC Public Health*. 2014;14:382.
66.Keadle SK, Shiroma EJ, Freedson PS, and Lee IM. Impact of accelerometer data processing decisions on the sample size, wear time and physical activity level of a large cohort study. *BMC Public Health*. 2014;14:1210.
67.Kelley DE, and Goodpaster BH. Effects of exercise on glucose homeostasis in Type 2 diabetes mellitus. *Med Sci Sports Exerc*. 2001;33(6 Suppl):S495-501; discussion S28-9.
68.Kerr J, Marshall SJ, Godbole S, et al. Using the SenseCam to improve classifications of sedentary behavior in free-living settings. *Am J Prev Med*. 2013;44(3):290-6.
69.Kim J, Tanabe K, Yokoyama N, Zempo H, and Kuno S. Objectively measured light-intensity lifestyle activity and sedentary time are independently associated with metabolic syndrome: a cross-sectional study of Japanese adults. *Int J Behav Nutr Phys Act*. 2013;10:30.
70.King AC, Rejeski WJ, and Buchner DM. Physical activity interventions targeting older adults. A critical review and recommendations. *Am J Prev Med*. 1998;15(4):316-33.
71.Kirkpatrick SI, Subar AF, Douglass D, et al. Performance of the Automated Self-Administered 24-hour Recall relative to a measure of true intakes and to an interviewer-administered 24-h recall. *Am J Clin Nutr*. 2014;100(1):233-40.
72.Knowler WC, Barrett-Connor E, Fowler SE, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002;346(6):393-403.
73.Kobayashi LC, Janssen I, Richardson H, Lai AS, Spinelli JJ, and Aronson KJ. A case-control study of lifetime light intensity physical activity and breast cancer risk. *Cancer Causes Control*. 2014;25(1):133-40.
74.Koepp GA, Manohar CU, McCrady-Spitzer SK, et al. Treadmill desks: A 1-year prospective trial. *Obesity (Silver Spring)*. 2013;21(4):705-11.
75.Kohl HW, 3rd, Craig CL, Lambert EV, et al. The pandemic of physical inactivity: global action for public health. *Lancet*. 2012;380(9838):294-305.
76.Kozey S, Lyden K, Staudenmayer J, and Freedson P. Errors in MET estimates of physical activities using 3.5 ml x kg(-1) x min(-1) as the baseline oxygen consumption. *J Phys Act Health*. 2010;7(4):508-16.
77.Kozey SL, Lyden K, Howe CA, Staudenmayer JW, and Freedson PS. Accelerometer output and MET values of common physical activities. *Med Sci Sports Exerc*. 2010;42(9):1776-84.
78.Kwon S, Mohammad J, and Samuel I. Physical activity patterns in morbidly obese and normal-weight women. *Am J Health Behav*. 2011;35(2):155-61.
79.Lanningham-Foster L, Nysse LJ, and Levine JA. Labor saved, calories lost: the energetic impact of domestic labor-saving devices. *Obes Res*. 2003;11(10):1178-81.
80.LaPorte RE, Montoye HJ, and Caspersen CJ. Assessment of physical activity in epidemiologic research: problems and prospects. *Public Health Rep*. 1985;100(2):131-46.

81.Larsen RN, Kingwell BA, Robinson C, et al. Breaking up of prolonged sitting over three days sustains, but does not enhance, lowering of postprandial plasma glucose and insulin in overweight and obese adults. *Clin Sci (Lond)*. 2015;129(2):117-27.
82.Larsen RN, Kingwell BA, Sethi P, Cerin E, Owen N, and Dunstan DW. Breaking up prolonged sitting reduces resting blood pressure in overweight/obese adults. *Nutr Metab Cardiovasc Dis*. 2014;24(9):976-82.
83.Laudani L, Vannozzi G, Sawacha Z, della Croce U, Cereatti A, and Macaluso A. Association between physical activity levels and physiological factors underlying mobility in young, middle-aged and older individuals living in a city district. *PLoS One*. 2013;8(9):e74227.
84.Lee IM, and Paffenbarger RS, Jr. Associations of light, moderate, and vigorous intensity physical activity with longevity. The Harvard Alumni Health Study. *Am J Epidemiol*. 2000;151(3):293-9.
85.Lee IM, and Shiroma EJ. Using accelerometers to measure physical activity in large-scale epidemiological studies: issues and challenges. *Br J Sports Med*. 2014;48(3):197-201.
86.Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet*. 2012;380(9838):219-29.
87.Lee S, Yuki A, Nishita Y, et al. Research relationship between light-intensity physical activity and cognitive function in a community-dwelling elderly population-an 8-year longitudinal study. *J Am Geriatr Soc*. 2013;61(3):452-3.
88.Levine JA. Non-exercise activity thermogenesis (NEAT). *Best Pract Res Clin Endocrinol Metab*. 2002;16(4):679-702.
89.Levine JA. Nonexercise activity thermogenesis (NEAT): environment and biology. *Am J Physiol Endocrinol Metab*. 2004;286(5):E675-85.
90.Littman AJ, Kristal AR, and White E. Effects of physical activity intensity, frequency, and activity type on 10-y weight change in middle-aged men and women. *Int J Obes (Lond)*. 2005;29(5):524-33.
91.Lohman TG, Harris M, Teixeira PJ, and Weiss L. Assessing body composition and changes in body composition. Another look at dual-energy X-ray absorptiometry. *Ann N Y Acad Sci*. 2000;904:45-54.
92.Loprinzi PD, and Brosky JA, Jr. Objectively measured physical activity and balance among U.S. adults. *J Strength Cond Res*. 2014;28(8):2290-6.
93.Loprinzi PD, Lee H, and Cardinal BJ. Daily movement patterns and biological markers among adults in the United States. *Prev Med*. 2014;60:128-30.
94.Loprinzi PD, Lee H, and Cardinal BJ. Evidence to Support Including Lifestyle Light-Intensity Recommendations in Physical Activity Guidelines for Older Adults. *Am J Health Promot*. 2014.
95.Loprinzi PD, Sheffield J, Tyo BM, and Fittipaldi-Wert J. Accelerometer-determined physical activity, mobility disability, and health. *Disabil Health J*. 2014;7(4):419-25.
96.Lord S, Chastin SF, McInnes L, Little L, Briggs P, and Rochester L. Exploring patterns of daily physical and sedentary behaviour in community-dwelling older adults. *Age Ageing*. 2011;40(2):205-10.

97.Lyden K, Keadle SK, Staudenmayer J, Braun B, and Freedson PS. Discrete features of sedentary behavior impact cardiometabolic risk factors. *Med Sci Sports Exerc*. 2015;47(5):1079-86.
98.Lynch BM, Dunstan DW, Healy GN, Winkler E, Eakin E, and Owen N. Objectively measured physical activity and sedentary time of breast cancer survivors, and associations with adiposity: findings from NHANES (2003-2006). *Cancer Causes Control*. 2010;21(2):283-8.
99.Maher C, Olds T, Mire E, and Katzmarzyk PT. Reconsidering the sedentary behaviour paradigm. *PLoS One*. 2014;9(1):e86403.
100.Maki KC, McKenney JM, Farmer MV, Reeves MS, and Dicklin MR. Indices of insulin sensitivity and secretion from a standard liquid meal test in subjects with type 2 diabetes, impaired or normal fasting glucose. *Nutr J*. 2009;8:22.
101.Martin KR, Koster A, Murphy RA, et al. Changes in daily activity patterns with age in U.S. men and women: National Health and Nutrition Examination Survey 2003-04 and 2005-06. *J Am Geriatr Soc*. 2014;62(7):1263-71.
102.Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the United States, 2003-2004. *Am J Epidemiol*. 2008;167(7):875-81.
103.Matthews CE, Moore SC, Sampson J, et al. Mortality Benefits for Replacing Sitting Time with Different Physical Activities. *Med Sci Sports Exerc*. 2015.
104.McArdle WD, Katch FI, and Katch VL. *Exercise Physiology: Nutrition, Energy, and Human Performance*. 7th ed. Baltimore, MD: Lippincott Williams & Wilkins 2010.
105.McClain JJ, Sisson SB, and Tudor-Locke C. Actigraph accelerometer interinstrument reliability during free-living in adults. *Med Sci Sports Exerc*. 2007;39(9):1509-14.
106.McLaughlin JE, King GA, Howley ET, Bassett DR, Jr., and Ainsworth BE. Validation of the COSMED K4 b2 portable metabolic system. *Int J Sports Med*. 2001;22(4):280-4.
107.Medicine ACoS. *ACSM's Guidelines for Exercise Testing and Prescription*. 7th Edition ed. Baltimore, MD: Lippincott Williams & Wilkins; 2006.
108.Medicine ACoS. *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription*. 6th Edition ed. Baltimore, MD: Lippincott, Williams, & Wilkins; 2010.
109.Mikines KJ, Sonne B, Farrell PA, Tronier B, and Galbo H. Effect of physical exercise on sensitivity and responsiveness to insulin in humans. *Am J Physiol*. 1988;254(3 Pt 1):E248-59.
110.Miller NE, Strath SJ, Swartz AM, and Cashin SE. Estimating absolute and relative physical activity intensity across age via accelerometry in adults. *J Aging Phys Act*. 2010;18(2):158-70.
111.Montoye HJ, Washburn R, Servais S, Ertl A, Webster JG, and Nagle FJ. Estimation of energy expenditure by a portable accelerometer. *Med Sci Sports Exerc*. 1983;15(5):403-7.
112.Morris JN, Heady JA, Raffle PA, Roberts CG, and Parks JW. Coronary heart-disease and physical activity of work. *Lancet*. 1953;265(6796):1111-20; concl.
113.Nichols JF, Morgan CG, Chabot LE, Sallis JF, and Calfas KJ. Assessment of physical activity with the Computer Science and Applications, Inc., accelerometer: laboratory versus field validation. *Res Q Exerc Sport*. 2000;71(1):36-43.

114.Norton K, Norton, L., Sadgrove, D. Position stand on physical activity and exercise intensity terminology. *Journal of Science and Medicine in Sport*. 2010;13:496-502.
115.Owen N, Salmon J, Koohsari MJ, Turrell G, and Giles-Corti B. Sedentary behaviour and health: mapping environmental and social contexts to underpin chronic disease prevention. *Br J Sports Med*. 2014;48(3):174-7.
116.Powers SK, and Howley ET. *Exercise Physiology: Theory and Application to Fitness and Performance*. 8th Edition ed. New York, NY: McGraw-Hill; 2012.
117.Ramadi A, Stickland MK, Rodgers WM, and Haennel RG. Impact of supervised exercise rehabilitation on daily physical activity of cardiopulmonary patients. *Heart Lung*. 2015;44(1):9-14.
118.Reid N, Eakin E, Henwood T, et al. Objectively measured activity patterns among adults in residential aged care. *Int J Environ Res Public Health*. 2013;10(12):6783-98.
119.Riou ME, Abdulnour J, Brochu M, Prud'homme D, Rabasa-Lhoret R, and Doucet E. Light physical activity is a better determinant of lower adiposity during the menopausal transition. *Climacteric*. 2014;17(1):79-86.
120.Santos-Lozano A, Santin-Medeiros F, Cardon G, et al. Actigraph GT3X: validation and determination of physical activity intensity cut points. *Int J Sports Med*. 2013;34(11):975-82.
121.Sapkota S, Bowles HR, Ham SA, Kohl HW, and Cdc. Adult participation in recommended levels of physical activity - United States, 2001 and 2003 (Reprinted from MMWR, vol 54, pg 1208-1212, 2005). *Jama-Journal of the American Medical Association*. 2006;295(1):27-9.
122.Sasaki JE, John D, and Freedson PS. Validation and comparison of ActiGraph activity monitors. *J Sci Med Sport*. 2011;14(5):411-6.
123.Services USDoHaH. *Physical activity and health: a report of the surgeon general.*: DIANE Publishing; 1996.
124.Shephard RJ. Absolute versus relative intensity of physical activity in a dose-response context. *Med Sci Sports Exerc*. 2001;33(6 Suppl):S400-18; discussion S19-20.
125.Smith HA, Storti KL, Arena VC, et al. Associations between accelerometer-derived physical activity and regional adiposity in young men and women. *Obesity (Silver Spring)*. 2013;21(6):1299-305.
126.Strath SJ, Bassett DR, Jr., and Swartz AM. Comparison of MTI accelerometer cut-points for predicting time spent in physical activity. *Int J Sports Med*. 2003;24(4):298-303.
127.Strath SJ, Kaminsky LA, Ainsworth BE, et al. Guide to the assessment of physical activity: Clinical and research applications: a scientific statement from the American Heart Association. *Circulation*. 2013;128(20):2259-79.
128.Strath SJ, Pfeiffer KA, and Whitt-Glover MC. Accelerometer use with children, older adults, and adults with functional limitations. *Med Sci Sports Exerc*. 2012;44(1 Suppl 1):S77-85.
129.Sugawara J, Inoue H, Hayashi K, Yokoi T, and Kono I. Effect of low-intensity aerobic exercise training on arterial compliance in postmenopausal women. *Hypertens Res*. 2004;27(12):897-901.

130.Swartz AM, Strath SJ, Bassett DR, Jr., O'Brien WL, King GA, and Ainsworth BE. Estimation of energy expenditure using CSA accelerometers at hip and wrist sites. *Med Sci Sports Exerc*. 2000;32(9 Suppl):S450-6.
131.Swartz AM, Strath SJ, Miller NE, Cashin SE, and Cieslik LJ. Glucose control and walking in a multiethnic sample of older adults. *Gerontology*. 2007;53(6):454-61.
132.Tanaka H, Monahan KD, and Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*. 2001;37(1):153-6.
133.Tremblay M. Reply to the Discussion of "Letter to the Editor: Standardized use of the terms sedentary and sedentary behaviours" - Sitting and reclining are different states. *Applied Physiology Nutrition and Metabolism-Physiologie Appliquee Nutrition Et Metabolisme*. 2012;37(6):1257-.
134.Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, and McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181-8.
135.Tudor-Locke C, Ham SA, Macera CA, et al. Descriptive epidemiology of pedometer-determined physical activity. *Med Sci Sports Exerc*. 2004;36(9):1567-73.
136.Tudor-Locke C, Johnson WD, and Katzmarzyk PT. Frequently reported activities by intensity for U.S. adults: the American Time Use Survey. *Am J Prev Med*. 2010;39(4):e13-20.
137.United States Department of Health and Human Services. *Physical Activity Guidelines Advisory Commitee Report*. Washington D.C. ; 2008. A-1 - A-10 p.
138.Wang H, Zhang T, Zhu W, Wu H, and Yan S. Acute effects of continuous and interval low-intensity exercise on arterial stiffness in healthy young men. *Eur J Appl Physiol*. 2014;114(7):1385-92.
139.Watson KB, Frederick GM, Harris CD, Carlson SA, and Fulton JE. U.S. Adults' Participation in Specific Activities: Behavioral Risk Factor Surveillance System--2011. *J Phys Act Health*. 2015;12 Suppl 1:S3-10.
140.Welch WA, Bassett DR, Freedson PS, et al. Cross-validation of waist-worn GENEA accelerometer cut-points. *Med Sci Sports Exerc*. 2014;46(9):1825-30.
141.Welch WA, Strath SJ, and Swartz AM. Congruent validity and reliability of two metabolic systems to measure resting metabolic rate. *Int J Sports Med*. 2015;36(5):414-8.
142.Welk GJ. *Physical activity assessments for health-related research*. Champaign, IL: Human Kinetics Publishers, Inc.; 2002, 16 p.
143.Wolever TM, and Jenkins DJ. The use of the glycemic index in predicting the blood glucose response to mixed meals. *Am J Clin Nutr*. 1986;43(1):167-72.
144.Wolff DL, Fitzhugh EC, Bassett DR, and Churilla JR. Waist-Worn Actigraphy: Population-Referenced Percentiles for Total Activity Counts in U.S. Adults. *J Phys Act Health*. 2014.

APPENDICES

Appendix A: Quality Criteria Checklist

Quality Criteria Checklist: Primary Research

RELEVANCE QUESTIONS	
1. Would implementing the studied intervention or procedure (if found successful) result in improved outcomes for the patients/clients/population group? (NA for some Epi studies)	Yes No Unclear N/A
2. Did the authors study an outcome (dependent variable) or topic that the patients/clients/population group would care about?	Yes No Unclear N/A
3. Is the focus of the intervention or procedure (independent variable) or topic of study a common issue of concern to dietetics practice?	Yes No Unclear N/A
4. Is the intervention or procedure feasible? (NA for some epidemiological studies)	Yes No Unclear N/A
If the answers to all of the above relevance questions are "Yes," the report is eligible for designation with a plus (+) on the Evidence Quality Worksheet, depending on answers to the following validity questions.	
VALIDITY QUESTIONS	
1. Was the research question clearly stated?	Yes No Unclear N/A
1.1 Was the specific intervention(s) or procedure (independent variable(s)) identified?	
1.2 Was the outcome(s) (dependent variable(s)) clearly indicated?	
1.3 Were the target population and setting specified?	
2. Was the selection of study subjects/patients free from bias?	Yes No Unclear N/A
2.1 Were inclusion/exclusion criteria specified (e.g., risk, point in disease progression, diagnostic or prognosis criteria), and with sufficient detail and without omitting criteria critical to the study?	
2.2 Were criteria applied equally to all study groups?	
2.3 Were health, demographics, and other characteristics of subjects described?	
2.4 Were the subjects/patients a representative sample of the relevant population?	
3. Were study groups comparable?	Yes No Unclear N/A
3.1 Was the method of assigning subjects/patients to groups described and unbiased? (Method of randomization identified if RCT)	
3.2 Were distribution of disease status, prognostic factors, and other factors (e.g., demographics) similar across study groups at baseline?	
3.3 Were concurrent controls used? (Concurrent preferred over historical controls.)	
3.4 If cohort study or cross-sectional study, were groups comparable on important confounding factors and/or were preexisting differences accounted for by using appropriate adjustments in statistical analysis?	
3.5 If case control study, were potential confounding factors comparable for cases and controls? (If case series or trial with subjects serving as own control, this criterion is not applicable. Criterion may not be applicable in some cross-sectional studies.)	
3.6 If diagnostic test, was there an independent blind comparison with an appropriate reference standard (e.g., "gold standard")?	
4. Was method of handling withdrawals described?	Yes No Unclear N/A
4.1 Were follow up methods described and the same for all groups?	
4.2 Was the number, characteristics of withdrawals (i.e., dropouts, lost to follow up, attrition rate) and/or response rate (cross-sectional studies) described for each group? (Follow up goal for a strong study is 80%.)	
4.3 Were all enrolled subjects/patients (in the original sample) accounted for?	
4.4 Were reasons for withdrawals similar across groups?	
4.5 If diagnostic test, was decision to perform reference test not dependent on results of test under study?	
5. Was blinding used to prevent introduction of bias?	Yes No Unclear N/A
5.1 In intervention study, were subjects, clinicians/practitioners, and investigators blinded to treatment group, as appropriate?	
5.2 Were data collectors blinded for outcomes assessment? (If outcome is measured using an objective test, such as a lab value, this criterion is assumed to be met.)	
5.3 In cohort study or cross-sectional study, were measurements of outcomes and risk	

	factors blinded?	
	5.4 In case control study, was case definition explicit and case ascertainment not influenced by exposure status?	
	5.5 In diagnostic study, were test results blinded to patient history and other test results?	
6.	**Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were intervening factors described?**	Yes No Unclear N/A
	6.1 In RCT or other intervention trial, were protocols described for all regimens studied?	
	6.2 n observational study, were interventions, study settings, and clinicians/provider described?	
	6.3 Was the intensity and duration of the intervention or exposure factor sufficient to produce a meaningful effect?	
	6.4 Was the amount of exposure and, if relevant, subject/patient compliance measured?	
	6.5 Were co-interventions (e.g., ancillary treatments, other therapies) described?	
	6.6 Were extra or unplanned treatments described?	
	6.7 Was the information for 6d, 6e, and 6f assessed the same way for all groups?	
	6.8 In diagnostic study, were details of test administration and replication sufficient?	
7.	**Were outcomes clearly defined and the measurements valid and reliable?**	Yes No Unclear N/A
	7.1 Were primary and secondary endpoints described and relevant to the question?	
	7.2 Were nutrition measures appropriate to question and outcomes of concern?	
	7.3 Was the period of follow-up long enough for important outcome(s) to occur?	
	7.4 Were the observations and measurements based on standard, valid, and reliable data collection instruments/tests/procedures?	
	7.5 Was the measurement of effect at an appropriate level of precision?	
	7.6 Were other factors accounted for (measured) that could affect outcomes?	
	7.7 Were the measurements conducted consistently across groups?	
8.	**Was the statistical analysis appropriate for the study design and type of outcome indicators?**	Yes No Unclear N/A
	8.1 Were statistical analyses adequately described the results reported appropriately?	
	8.2 Were correct statistical tests used and assumptions of test not violated?	
	8.3 Were statistics reported with levels of significance and/or confidence intervals?	
	8.4 Was "intent to treat" analysis of outcomes done (and as appropriate, was there an analysis of outcomes for those maximally exposed or a dose-response analysis)?	
	8.5 Were adequate adjustments made for effects of confounding factors that might have affected the outcomes (e.g., multivariate analyses)?	
	8.6 Was clinical significance as well as statistical significance reported?	
	8.7 If negative findings, was a power calculation reported to address type 2 error?	
9.	**Are conclusions supported by results with biases and limitations taken into consideration?**	Yes No Unclear N/A
	9.1 Is there a discussion of findings?	
	9.2 Are biases and study limitations identified and discussed?	
10.	**Is bias due to study's funding or sponsorship unlikely?**	Yes No Unclear N/A
	10.1 Were sources of funding and investigators' affiliations described?	
	10.2 Was there no apparent conflict of interest?	

MINUS/NEGATIVE (-)

If most (six or more) of the answers to the above validity questions are "No," the report should be designated with a minus (-) symbol on the Evidence Quality Worksheet.

NEUTRAL (∅)

If the answers to validity criteria questions 2, 3, 6, and 7 do not indicate that the study is exceptionally strong, the report should be designated with a neutral (∅) symbol on the Evidence Quality Worksheet.

PLUS/POSITIVE (+)

If most of the answers to the above validity questions are "Yes" (including criteria 2, 3, 6, 7 and at least one additional "Yes"), the report should be designated with a plus symbol (+) on the Evidence Quality Worksheet.

Appendix B. PRISMA 2009 Checklist for Systematic Reviews

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2 - 3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5 - 6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	NA
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6 - 7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	6
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6-7, Fig.1
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA

Page 1 of 2

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	7
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6, Fig 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Supplemental Table
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	7
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Supplemental Table
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	NA
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	NA
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	25-26
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	26-28
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	26-29
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA, not funded

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

Appendix C: Screening Form: Contextual analysis of physical activities in older adults

Physical Activity & Health Research Lab

Department of Kinesiology

Enderis Hall, Rm. 434 • (414)229-4392

Screening Form for Contextual analysis of physical activity in older adults

Name:_____ Phone:_____

Address:_____

_____E-mail: _____

Hello, my name is _____ and I am a_____ working with the Physical Activity & Health Research Laboratory at the University of Wisconsin- Milwaukee. You have indicated that you are interested in participating in exercise research with our Lab. Before I tell you about the study, do you mind if I ask you a few questions about yourself to determine if you qualify for the study?

1. What is your current age?_____ Date of birth: _____

   *The individual qualifies if aged 60 years or older.

2. Are you able to walk for 3-minutes unassisted? ☐ **Yes**

   ☐ No

3. Do you have any limitations to walking such as the use of a cane or any limping? ☐ Yes ☐ **No**

4. Do you have any lower limb amputations? ☐ Yes ☐ **No**

5. Do you have a current history an orthopedic

condition that may preclude you from being physically active? □ Yes

□ **No**

6. Is there any other condition we should know about that could prevent you from participating in a research study involving physical activity? □ Yes

□ **No**

*****They are eligible to participate if they:**

- ARE 60 YEARS OLD OR OLDER
- ANSWER "YES" TO QUESTION 2
- ANSWER "NO" TO QUESTIONS 3-6

IF THEY QUALIFY…

You are one of 150 individuals who are being asked to participate in this study at the University of Wisconsin-Milwaukee. The study involves 2 visits, each lasting approximately 30 minutes.

Study Overview:

The study will be conducted during two visits. Visit one will last about 30 minutes and involve the completion of a health history questionnaire, and a handedness questionnaire. Height and weight can be completed at visit 1 or visit 2. You will be asked to complete a 7-day physical activity-monitoring period, wearing 2 activity monitors, one worn on the wrist and one on the hip. On one day we will ask you to fill in a physical activity diary, where you will record each activity you do throughout one waking day, and a wearable camera that is worn around your neck. The second visit will last about 30 minutes. During this visit we will collect all the activity monitoring equipment (2 monitors, diary, and camera), ask you complete physical activity questionnaires, and complete a 9-minute walk test. The 9-minute walk test involves walking for 3 minutes slower than your normal pace, 3 minutes at your normal pace, and 3 minutes faster than your normal pace. During the walk test we will ask you to wear two motion sensors, one placed on your wrist, one placed on your hip, and a portable energy expenditure assessment device that captures expired breath and a heart rate monitor to measure heart rate.

Do you have any questions about the project?

Just a few more questions…

1. Is there any reason why you cannot complete this study?

□ Yes □ **No**

2. Do you have any medical conditions which would interfere with the study?

□ Yes □ **No**

Are you still interested? IF YES, SCHEDULE THEM FOR THE STUDY

Send directions to UWM, if applicable: _____ initials

IF THEY DO NOT QUALIFY…

Unfortunately, due to _____ you do not qualify to participate this project at this time. If you would like to hear about other studies currently taking place in the Physical Activity & Health Research Lab, I would like to share details with you regarding one that will be more fitting for you. Would you like to hear about such studies now? □ Yes □ **No**

Initials and date of person who filled out this form_____

Appendix D: Informed Consent: Contextual analysis of physical activities in older adults

UNIVERSITY OF WISCONSIN – MILWAUKEE
CONSENT TO PARTICIPATE IN RESEARCH

THIS CONSENT FORM HAS BEEN APPROVED BY THE IRB FOR A ONE YEAR PERIOD

1. General Information

Study title:
Contextual Analysis of Physical Activities in Older Adults

Person in Charge of Study (Principal Investigator):

Ann M. Swartz, Ph.D.
Professor
Department of Kinesiology
University of Wisconsin-Milwaukee

Whitney Welch, M.S.
Doctoral Candidate
Department of Kinesiology
University of Wisconsin-Milwaukee

2. Study Description

You are being asked to participate in a research study. Your participation is completely voluntary. You do not have to participate if you do not want to.

Study description:
The purpose of this study is to the types of activities that older adults perform and where they are being performed. You will be one of 150 adults (aged 60+ years) asked to report to the Physical Activity & Health Research Laboratory on UWM's Campus (Enderis Hall, room 434) or meet with a study staff member at an agreed upon location on two occasions to complete the study. Each study visit will be at least seven days apart. Each study visit will be about 30 minutes. Completion of all study components will take one week.

3. Study Procedures

What will I be asked to do if I participate in the study?
If you agree to participate you will be asked to come to the Physical Activity & Health Research Laboratory on UWM's Campus (Enderis Hall, room 434) for two study visits where you will be asked to complete the following tasks:

Visit 1 (Approximately 30 minutes)
At the time of this visit you will be given an introduction to the study and sign this informed consent document.

Demographic Assessments (15 minutes):
You will be asked to complete a questionnaire on your health status and handedness.

Activity Monitors (15 minutes):
You will be asked to wear a few small match-boxed sized devices (accelerometers) for 7 consecutive days on a provided belt and/or around your wrist fastened with a provided velcro strap. You will receive instructions on the correct use and wear of the accelerometers. We will also ask you to complete a 7 day activity log during this monitoring period. This device and log will give us a measure of your current physical activity level. The monitors will be worn all waking hours and taken off during sleep. During one day of the monitoring week we will ask you to record all your activity to a physical activity diary that will track the activity you are performing, where you are, and with whom. During this time, we will also show you how to wear and use a small digital camera that is placed around your neck and takes still shot pictures. We will ask you to wear this on the same day you are completing the diary.

Monitoring Week:
Following visit 1, you will wear the accelerometer for seven consecutive days during all waking hours as instructed during visit 1, except for bathing/showering or activities in which you are submerged in water.

Visit 2 (Approximately 45 minutes)
Prior to this visit we ask that you refrain from food, calorie containing beverages, or any stimulants such as caffeine for 4 hours, refrain from exercise for 12 hours. Physican prescribed medication should be taken as usual.

Anthropometric Assessments: (Approximately 5 minutes)
We will measure your height and weight.

9-Minute Walk Test Protocol (10 minutes)
You will complete 3, 3-minute stages of walking; one stage at a pace slower than your normal walking pace, one at your normal walking pace, and one at your faster

than normal walking pace. The test will take place over ground on a hard, flat surface. You will be able to take a break in between each 3-minute speed change, if needed. The study staff member will be following alongside you during the duration of the walk test to assist if at any time you feel uncomfortable to complete the walk test. During each stage we will analyze the air you expire for oxygen and carbon dioxide to determine how many calories you are burning as was done during the uninterrupted seated condition. Additionally, you will wear a heart rate monitor and measure your heart rate during these three walking conditions.

Completion of pen and paper surveys: (approximately 30 minutes)
We will ask you to complete different pen and paper surveys that will be asking you about your physical activity.

4. Risks and Minimizing Risks

What risks will I face by participating in this study?

The portable metabolic system is a lightweight system that seeks to limit any additional load carried by the participant during daily activities. The portable metabolic system facemask that is worn over your nose and mouth may cause slight discomfort, such as pressure from wear.

The information collected in this study is kept strictly confidential. Only the people directly involved in this study will have access to the information. Your name will never be associated with any of the information collected or the picture we take of you. Your name and photo will be associated with an identification number that which will not allow your information to be traced back to this research study. We may decide to present what we find to others, or publish our results in scientific journals or at scientific conferences. If this happens, your name will never be associated with any of the data collected, and your identity will always remain strictly confidential. All research data is stored electronically on a password-protected computer as well as in hard copy in a locked cabinet.

As with any research study, there may be additional risks of participating that are unforeseeable or hard to predict.

5. Benefits

Will I receive any benefit from my participation in this study?
Yes, we will provide you with information on your height, weight, and current activity level.

6. Study Costs and Compensation

Will I be charged anything for participating in this study?
You will not be responsible for any of the costs from taking part in this research study.

Are subjects paid or given anything for being in the study?
No monetary compensation will be given for participation in this study.

7. Confidentiality

What happens to the information collected?
All information collected about you during the course of this study will be kept confidential to the extent permitted by law. We may decide to present what we find to others, or publish our results in scientific journals or at scientific conferences. Only the PI and associated laboratory personnel will have access to the information. However, the Institutional Review Board at UW-Milwaukee or appropriate federal agencies like the Office for Human Research Protections may review this study's records. All the information collected in this study will be stored in Enderis Hall 434 for five years for future use.

With your permission, we may take photos of you participating in this study. The photo may be used in presentations at scientific meetings or in research publications in order to describe the study. Your face will not be included in the photos we use in any presentation or publication. Photos will be stored electronically in the secure server within UWM that is password protected. Electronic data will be stored in a secure server within UWM that is password protected and print data will be stored in the locked file cabinet in the laboratory. Participant names will be removed from the data using black ink within a year of collection once the data are checked for any error. A key that links the ID numbers with names will be stored in a separate file electronically. Only the laboratory members will have access to these data.

8. Alternatives

Are there alternatives to participating in the study?
There are no known alternatives available to you other than not taking part in this study.

9. Voluntary Participation and Withdrawal

What happens if I decide not to be in this study?
Your participation in this study is entirely voluntary. You may choose not to take part in this study. If you decide to take part, you can change your mind later and withdraw from the study. You are free to not answer any questions or withdraw at any time. Your decision will not change any present or future relationships with the University of Wisconsin Milwaukee. We will use the information collected to that point.

10. Questions

Who do I contact for questions about this study?
For more information about the study or the study procedures or treatments, or to withdraw from the study, contact:

Ann M. Swartz, Ph.D.
Professor
Department of Kinesiology
2400 E. Hartford Ave.
414-229-4242

Who do I contact for questions about my rights or complaints towards my treatment as a research subject?
The Institutional Review Board may ask your name, but all complaints are kept in confidence.

Institutional Review Board
Human Research Protection Program
Department of University Safety and Assurances
University of Wisconsin – Milwaukee
P.O. Box 413
Milwaukee, WI 53201
(414) 229-3173

11. Signatures

Research Subject's Consent to Participate in Research:
To voluntarily agree to take part in this study, you must sign on the line below. If you choose to take part in this study, you may withdraw at any time. You are not giving up any of your legal rights by signing this form. Your signature below indicates that you

have read or had read to you this entire consent form, including the risks and benefits, and have had all of your questions answered, and that you are 18 years of age or older.

_____
Printed Name of Subject/ Legally Authorized Representative

_____ _____
Signature of Subject/Legally Authorized Representative Date

Research Subject's Consent to Audio/Video/Photo Recording:

It is okay to photograph me while I am in this study and use my photographed data in the research.

Please initial: ___Yes ___No

Principal Investigator (or Designee)
I have given this research subject information on the study that is accurate and sufficient for the subject to fully understand the nature, risks and benefits of the study.

_____ _____
Printed Name of Person Obtaining Consent Study Role

_____ _____
Signature of Person Obtaining Consent Date

Appendix E: Health History Questionnaire: Contextual analysis of physical activities in older adults

PROJECT ID	HEALTH HISTORY AND DEMOGRAPHIC QUESTIONNAIRE	CURRENT DATE
_____		_____

Address: _____

City: _____ **Zip Code:** _____

Phone: _____ **Date of Birth:** _____ **Current Age:** _____

Gender (circle one): M F If Female, have you reached menopause? (circle one) Yes No

If YES, at what age? _____

Senior Center Member (circle one): Yes No

Do You Have Access to a Car? (circle one): Yes No

Do You Live Alone? (circle one): Yes No

Current or Former Occupation: _____ **Full Time? (circle one):** Yes No

Marital Status (circle one): Single Married Divorced Widowed

Education (circle highest level completed): Elementary High School College Graduate School

Race (circle ethnicity): White American Indian Asian Hispanic

Black / African American Native Hawaiian / Pacific Islander

Household Income Level per year (circle one):

< $5,000 per year $5,000 - $14,999 $15,000 - $24,999

$25,000 - $34,999 $35,000 - $49,999 > $50,000

Are you taking any prescription or over-the counter medication? (circle one) YES NO

If YES, please indicate the names, reasons, and how long you have been taking the medication below.

Name of Medication Reason for Taking For How Long?

Emergency Contact Information:

Name: _____

Relationship: _____ Phone: _____

Personal Physician Name: _____ **Location:** _____

YOUR PAST HEALTH HISTORY	**FAMILY HEALTH HISTORY**
Circle any of the following medical conditions you have either been diagnosed with or have experienced.	**Circle any of the following medical conditions experienced by any immediate family and indicate who has/had the condition and when (brothers/sisters, children, parents).**
High blood pressure Stroke	Heart attacks Stroke
Any heart problems Blood Clots	High blood pressure Early death
Arthritis Cancer	High cholesterol Diabetes
Diabetes	Congenital heart defect
Recurring leg pain (not related to arthritis)	Heart operations
Liver or Kidney Disease	Other family illnesses _____
Any breathing or lung problems	_____
Ankle swelling (not related to twisting)	

YOUR PRESENT HEALTH (SIGNS & SYMPTOMS)

Circle any of the following signs and symptoms you are currently experiencing (within the last year).

Chest pain / discomfort	Cough on exertion	Difficulty standing from an armless chair
Shortness of breath	Coughing of blood	Difficulty lifting/carrying something
Heart palpitations	Dizzy spells	Difficulty doing chores around the house
Skipped heart beats	Frequent headaches	Difficulty standing for greater than 2 hours
Heart Attack	Orthopedic / joint problems	
Diabetes	Back Pain	

Have you been hospitalized in the last year?(circle one) Yes No

Have you ever had your cholesterol measured? (circle one) YES NO If YES, (list value) ____

Do you currently smoke? (circle one) YES NO If YES, what? (circle) Cigarettes Cigars Pipe

How much per day: (circle one) < 0.5 pack 0.5 to 1 pack 1.5 to 2 packs >2 packs

Have you ever quit smoking? (circle one) YES NO If YES, how old were you when you quit?

How many years did you smoke? _____

Do you drink alcoholic beverages? (circle one) YES NO If YES, how many beverages in 1 week? ___

Appendix F: Edinburgh Handedness Inventory[1]

Your Initials:_____

Please indicate with a check (✓) your preference in using your left or right hand in the following tasks.

Where the preference is so strong you would never use the other hand, unless absolutely forced to, put two checks (✓✓).

If you are indifferent, put one check in each column (✓ | ✓).

Some of the activities require both hands. In these cases, the part of the task or object for which hand preference is wanted is indicated in parentheses.

Task / Object	Left Hand	Right Hand
1. Writing		
2. Drawing		
3. Throwing		
4. Scissors		
5. Toothbrush		
6. Knife (without fork)		
7. Spoon		
8. Broom (upper hand)		
9. Striking a Match (match)		
10. Opening a Box (lid)		

[1] Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsycholoolgia*, *9*, 97-113.

Appendix G: Activity Log - Contextual Analysis of Physical Activities in Older Adults

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Date							
Day of Week							
Monitor Time On in the morning							
Monitor Time Off in the evening							
List any times you removed the monitors during the day							
Exercise							
Camera Worn?							

Appendix H: Actigraph Accelerometer Instructions

UWM physical activity and health research lab
Department of Kinesiology
Enderis Hall, Rm. 434 • (414)229-4392

ACTIGRAPH ACCELEROMETER INSTRUCTIONS

1. Please wear the 2 Actigraph accelerometers as shown in the picture for 7 days.
   - One on your right hip on the belt (labeled Hip), so all you need to do is position the belt around your waist

   - One on your non-dominant wrist fastened by Velcro strap (labeled wrist)

2. The accelerometers should be placed with the black screw cap facing up. Fasten the Velcro straps so they are snug on the "fingernail" side of the wrist where you would wear a watch, not the palm side, again with the black screw cap facing up. Keep the belt nice and tight so that the accelerometer fits snugly against your hip. Refer to photos above for proper placement of accelerometers.

3. Wear the accelerometers all day – from the moment you get up to the moment you go to bed. You should not wear the accelerometers when you bath, shower, or swim.

4. When you take your accelerometers off at bed time, leave them in a place where you will see it first thing in the morning. Good places are next to your glasses or alarm clock.

   (If you think you may have trouble remembering to put the accelerometer on in the morning, leave yourself a note. For instance, put a note on your fridge door to remind yourself.)

5. Please go about your "normal" activity for the next seven days.

Appendix I: Physical Activity Diary

Contextual Analysis of Physical Activities in Older Adults

Directions: Record the time and subsequent activity indicators each time you begin a new activity.

Time
Record the time. Circle AM or PM.

Behavior
What is the activity that you are currently doing?
Ex. Walking, Cooking, Watching TV, Reading a book, Laundry, etc.

Posture
What posture is your body currently in?
Ex. Sitting, Standing, Lying down, etc.

Location
Where are you currently?
Ex. Inside, Outside, Living Room, Grocery Store, Library, Senior Center

Intensity
How hard do you feel you are working?
No effort, Light effort, moderate effort, hard effort

Social Interaction
Are you interacting with someone else? Who?
Ex. Yes/No; Ex. Friend, Sister, Grandchild, Clerk, Nurse, etc.

Example:

Time	Behavior	Posture	Location	Intensity	Social Interaction
1:20 PM	Watching TV	Sitting	Living Room	Sedentary	No
1:42 PM	Walking	Standing	Lake Park	Moderate	Female, Friend
2:30 PM	Cooking	Standing	Kitchen	Light	No

Time	Activity	Posture (sitting, standing, lying, etc.)	Location (inside/ outside; park, kitchen)	Intensity (no effort, light, moderate, vigorous effort)	Social Interaction (yes/no; sister, friend)
AM/PM					
AM/PM					
AM/PM					
AM/PM					
AM/PM					
AM/PM					
AM/PM					

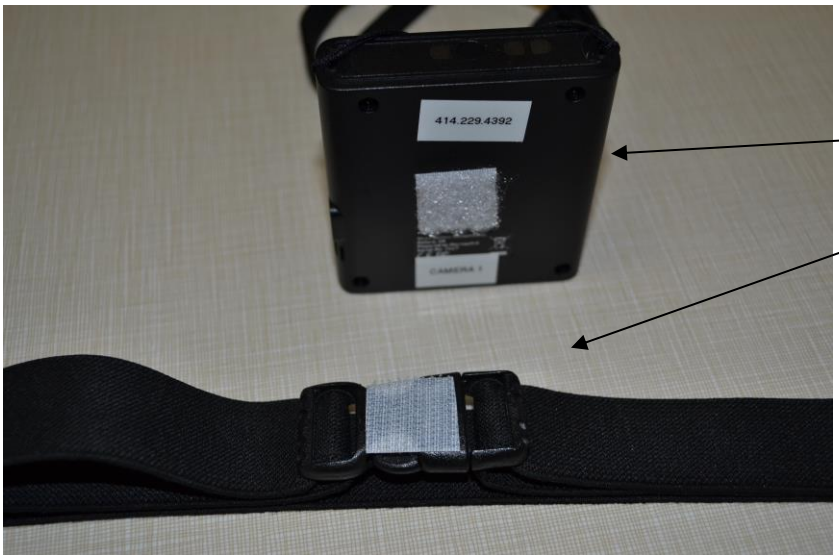
Appendix J: Wearable Camera Instructions

Department of Kinesiology
Enderis Hall, Rm. 434 • (414)229-4392

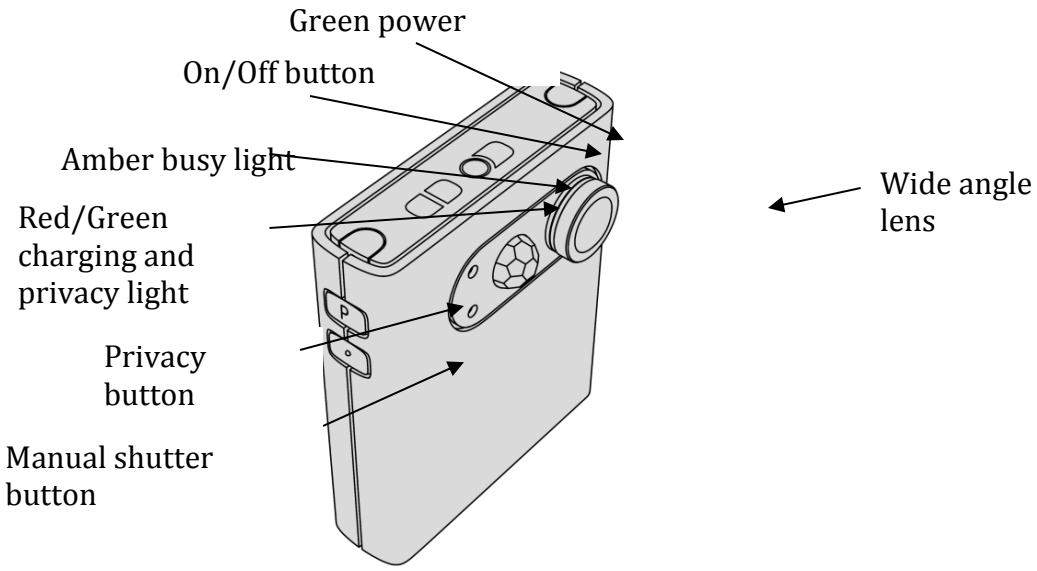
SENSECAM/VICON REVUE CAMERA INSTRUCTIONS

SENSECAM

1. Please wear the camera all waking hours on 1 of the 7 days you will be monitoring your physical activity.
   - Day 1: _____
2. Wear the camera around your neck and adjust the strap such that the camera sits on the sternum. Be sure the camera is on the outside of your clothing, including a jacket or coat if you go outside.
3. Please attach the elastic belt via Velcro and strap around your chest to secure it in place.

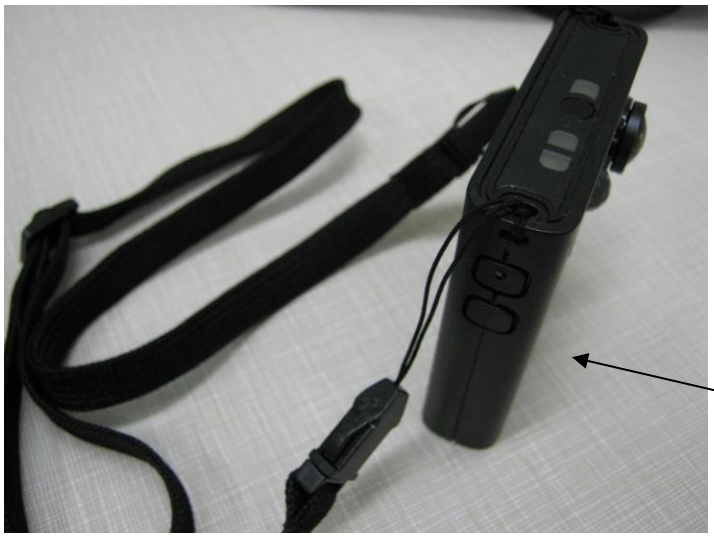


4. Turn the camera on by pressing and holding (for a few seconds) the small round On/Off button on the top of the camera. A rising tone indicates the camera is switching on.



5. There will be a green power light on when the camera is on and it will flash yellow each time it takes a photo.

6. Please press the "P" privacy button on the side of the camera at any time you do not want a photo recollection of your daily activity, such as using the rest room. This will stop the camera from taking photos for 4 minutes and a red light will shine indicating a temporary suspension in taking photos. It will beep 15 seconds prior to taking photos again. If you need extra time, press the "P" button on the side and it will stop for another 4 minutes.



7. Turn camera off by pressing and holding (for a few seconds) the small round button on the top of the camera. A falling tone indicates the camera is powering off.
8. The camera will hold the charge for 12 hours, once it has died you can remove the camera. Please note this time on your activity log.

NOTES:

- The Sensecam will blink.

Please return all equipment at your second visit. **Please call if there are any concerns.**

Appendix K: INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

☐ Yes

☐ No → ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

_____ **days per week**

☐ No vigorous job-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

_____ **hours per day**

_____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

_____ **days per week**

☐ No moderate job-related physical activity → ***Skip to question 6***

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**

_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking → ***Skip to PART 2: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**

_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐ No traveling in a motor vehicle → ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**

_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No bicycling from place to place → ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**

_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days *walking* ***from place to place?***

_____ **hours per day**

_____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**

_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

_____ **days per week**

☐ No moderate activity in garden or yard → ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**

_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home → ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**

_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐ No walking in leisure time → ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**

_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

_____ **days per week**

☐ No vigorous activity in leisure time → ***Skip to question 24***

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**

_____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ **days per week**

☐ No moderate activity in leisure time → ***Skip to PART 5: TIME SPENT SITTING***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?

_____ **hours per day**

_____ **minutes per day**

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ **hours per day**

_____ **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ **hours per day**

_____ **minutes per day**

This is the end of the questionnaire, thank you for participating.

Appendix L: Screening Form: Response between time spent in light intensity physical activity and glucose dynamics in older adults

Physical Activity & Health Research Lab

UWM UNIVERSITY of WISCONSIN MILWAUKEE

Department of Human Movement Sciences

Enderis Hall, Rm. 434 • (414)229-4392

Screening Form for Dose-Response of Light Intensity Physical Activity and Glucose Dynamics in Older Adults

Call log: Date/ Time Comment

_____

_____

Hello, my name is _____and I am a researcher working with the Physical Activity & Health Research Laboratory at the University of Wisconsin- Milwaukee. You have indicated that you are interested in participating in research with our Lab. If you have a moment, please let me tell you about a study that we are currently working on. Do you mind if I ask you a few questions about yourself to determine if you qualify for the study?

7. What is your current age?_____ Date of birth: _____
   *The individual qualifies if aged >60 years.
8. How tall are you? _____in

9. What is your weight? _____lbs _____kg (does not qualify if >300 lb; 136 kg)
   BMI: _____ * qualifies if ≥25 kg/m^2

10. On average, how many minutes per day would you say you participate in moderate or vigorous physical activity? _____ (qualifies if <150 minutes/week)

11. Have you fractured a lower limb in the last three months? ☐ Yes ☐ **No**

12. Have you had an amputation other than toes? ☐ Yes ☐ **No**

13. Do you use any assistive device such as a cane or walker? ☐ Yes ☐ **No**

14. Do you limp? ☐ Yes ☐ **No**

15. Do you have any limitations to walking on a treadmill? ☐ Yes

☐ **No**

16. Do you ever have any of the following symptoms at rest?

Shortness of breath	☐ Yes ☐ **No**
Dizziness	☐ Yes ☐ **No**
Tightness or pain in the chest	☐ Yes ☐ **No**
Unusual fatigue	☐ Yes ☐ **No**

*****They are eligible to participate if individual:**

- ANSWERS "NO" TO QUESTIONS 5-10 ABOVE
- IS OVER THE AGE OF 60 YEARS
- BMI ≥25 kg/m^2
- Weight <300 lbs or 136 kg

IF THEY QUALIFY…

You are one of 15 individuals who are being asked to participate in this study at the Physical Activity & Health Research Laboratory of the University of Wisconsin-Milwaukee. The study involves four visits to the laboratory lasting approximately 3-4 hours.

Visit 1: On the day of your testing session, you will report to the Physical Activity &Health Research Laboratory where you will be given an introduction to the study and sign an informed consent document. We will also ask you to provide us with some information on your health history and the health history of your family. During this visit we will also measure your height and weight. During this visit we will ask you to sit uninterrupted for three hours. During this time, we will ask you to wear a portable energy expenditure assessment device that captures expired breath and a heart rate monitor to measure heart rate. Additionally, a finger blood sample will be taken at the beginning of the 3-hour condition and at each hour for a total of 4 samples. At the end of the three hours we will ask you to complete a treadmill-walking test (walking at 1, 1.5, and 2 mph) to determine your light intensity activity. During this time we will also ask you to complete two questionnaires, one which will ask questions about your activity level and one about your current food intake. Finally, we will have you complete a dual-energy x-ray absorptiometry scan to provide information of body composition. This visit will take approximately 4 hour. You will be asked to wear one, small match-boxed sized device, called an accelerometer, for

7 consecutive days. You will receive instructions on the correct use and wear of the accelerometer. This device will give us a measure of your current physical activity level.

For seven days of that week, you will be asked to wear the accelerometer.

Visit 2-4:
Visits 2-4 will each involve wearing the portable energy expenditure assessment device and heart monitor to capture energy expenditure and heart rate, respectively for 3 hours. During each visit we will ask you to engage in light intensity physical activities (ex. Treadmill walking, laundry, playing cards, light calisthenics, etc) for differing amounts of time (36, 72, 108 min) with the remainder of the 3 hours spent seated. Again, a finger blood sample will be taken at the beginning of the 3-hour condition and at each hour for a total of 4 samples. During this time we will also ask you to complete two questionnaires, one which will ask questions about your activity level and one about your current food intake.

Do you have any questions about the project?

Just a few more questions…

3. Is there any reason why you cannot complete this study?
   ☐ Yes ☐ **No**
4. Do you have any medical conditions which would interfere with the study.
   ☐ Yes ☐ **No**

Are you still interested? IF YES, SCHEDULE THEM FOR THE STUDY

IF THEY DO NOT QUALIFY…

Unfortunately, due to _____ you do not qualify to participate in this study at this time. If you would like to hear about other studies currently taking place in the Physical Activity and Health Research Lab, I would like to share details with you regarding one that will be more fitting for you. Would you like to hear about such studies now? ☐ Yes ☐ **No**

Initials and date of person who filled out this form_____

Appendix M: Informed Consent: Dose Response between time spent in light intensity physical activity and glucose dynamics in older adults

UNIVERSITY OF WISCONSIN – MILWAUKEE
CONSENT TO PARTICIPATE IN RESEARCH

THIS CONSENT FORM HAS BEEN APPROVED BY THE IRB FOR A ONE YEAR PERIOD

1. General Information

Study title:

Dose-Response between time spent in light intensity physical activity and glucose dynamics in older adults.

Person in Charge of Study (Principal Investigator):

Ann M. Swartz, Ph.D.
Associate Professor
Department of Kinesiology
University of Wisconsin-Milwaukee

Whitney Welch, M.S.
Doctoral Candidate
Department of Kinesiology
University of Wisconsin-Milwaukee

2. Study Description

You are being asked to participate in a research study. Your participation is completely voluntary. You do not have to participate if you do not want to.

Study description:

The purpose of this study is to determine the effect different amounts time spent in light intensity physical activities has on blood sugar over a three-hour period. You will be one of 15 adults (aged 60+ years) asked to report to the Physical Activity & Health Research Laboratory on UWM's Campus (Enderis Hall, room 434) on four occasions to complete the study. Each study visit will be at least seven days apart. Each study visit will last between 3.5-4 hours. Completion of all study components will take at least four weeks.

3. Study Procedures

What will I be asked to do if I participate in the study?
If you agree to participate you will be asked to come to the Physical Activity & Health Research Laboratory on UWM's Campus (Enderis Hall, room 434) for four laboratory visits where you will be asked to complete the following tasks:

Visit 1 (4.0 hours)
Parking will be provided near the laboratory, and directions will be given to you if you drive. At the time of this visit you will be given an introduction to the study and sign this informed consent document.

Prior to this visit we ask that you refrain from food, calorie containing beverages, any stimulant such as caffeine for 4 hours and refrain from exercise for 12 hours, wear comfortable clothing, and avoid wearing metal for the body composition test. Physician prescribed medication should be taken as usual.

Demographic & Anthropometric Assessments (15 minutes):
You will be asked to complete a questionnaire on your current and past health status. During this visit we will measure your body height and weight.

Body Composition Testing: (approximately 20 minutes)
We will measure your body fat level using a dual-energy x-ray absorptiometer or DEXA scan. This is a common and painless procedure that involves lying still on a padded table for approximately 10 minutes while the machine takes an x-ray picture of your whole body. During the test you will be able to breathe normally. Because the test involves taking an x-ray picture of your whole body, you will be exposed to radiation. However, the amount of radiation used for this test is very low. It is about the same amount one would get on a long plane flight (from New York to Los Angeles) and much less than one is exposed to during a typical chest x-ray. This test is included solely for research purposes and is not considered part of your standard clinical care. There is no need to stop taking any medicines, follow a special diet, or limit activity in any way before the test. Please do not wear clothing with any metal (buttons, snaps, or zippers) on the day of the test. If you do wear metal, we will ask you to remove it for the test. If you have recently had x-ray tests using barium or any nuclear medicine tests, you should have your bone density test at least a week after those tests. It is very important to tell the researcher if you are breast feeding at the time of the test.

Uninterrupted Seated Condition (3.0 hours):
You will be asked sit for three continuous hours. You will be asked to remain seated for three hours. During this time you will be able to read, watch television, do computer work, knit etc., however you will remain seated throughout the entire three hours.

Directly prior to beginning the three hour measurement, you will be asked to consume a liquid meal (8 fl oz Ensure PLUS). This allows us to simulate how the different conditions would affect your blood sugar levels following consuming a meal.

During this three-hour time period we will be monitoring the air you breathe by putting a facemask over your nose and mouth. You will be able to breathe feely in and out of the facemask. We will analyze the air you expire for oxygen and carbon dioxide to determine how many calories you are burning and how much fat and carbohydrate you were using. In addition, you will wear a heart rate monitor or a plastic strap around your chest that transmits your heart rate (beats/min). Finally, we will collect blood at four separate time points during the condition (one at the start of the condition and one each hour; hour 1, hour 2, hour 3). The blood will be collected from the tip of a finger. A different fingertip can be used for each finger prick. The total amount of blood removed is small (0.02 teaspoons) and will not be detrimental to your health. We will use the collected blood to measure your blood sugar level.

International Physical Activity Questionnaire: (approximately 15 minutes)
During the three hour sitting bout, you will be asked to complete a survey regarding the usual amount of physical activity over the past seven days. There are a total of 27 questions, highlighting different aspects of your day asking what types of activities you may or may not have engaged in. For example: "During the last 7 days how many days did you do moderate activities like carrying light loads, sweeping, washing windows, and raking in the garden or yard."

24-hour Dietary Recall Survey (20 minutes)
During the three hour sitting bout, you will be asked to complete a survey on the computer in the lab asking you questions about all the food and drink you have had over the past day. Questions will consist of information on for what meal the food/drink was consumed (breakfast, lunch, dinner, snack), at what time the food/drink was consumed, and where the food/drink was consumed. This can be completed during the three-hour seated condition.

Treadmill Walking Protocol (15 minutes)
After the three hour sitting bout, you will be asked to complete 3, 5-minute stages of walking on the treadmill; one stage at 1.0 mph, one at 1.5 mph, and one at 2.0 mph. During each stage we will continue to analyze the air you expire for oxygen and carbon dioxide to determine how many calories you are burning as was done during the uninterrupted seated condition.

Monitoring Week:
Following visit 1, you will wear a single accelerometer for seven consecutive days during all waking hours as instructed during visit 1, except for bathing/showering

or activities in which you are submerged in water. The monitor will be worn around your waist on a provided elastic belt.

Visit 2-4 (Approximately 3.5 hours)

Parking will be provided near the laboratory, and directions will be given to you if you drive.

Prior to this visit we ask that you refrain from food, calorie containing beverages, any stimulant such as caffeine for 4 hours, refrain from exercise for 12 hours, wear comfortable clothing, and maintain a similar diet 24 hours prior to visits 2-4 as was consumed prior to visit 1. Physican prescribed medication should be taken as usual.

Anthropometric Assessments: (Approximately 5 minutes)

We will measure your weight.

Activity Conditions (3.0 hours):

You will be asked to complete three different activity conditions on each of the three visits (visits 2-4): condition 1, condition 2, and condition 3. All activity conditions contain the same activities; however, the amount of time spent in active and sedentary behaviors differs. When the activity portion is completed, participants will complete the remaining time in a seated position. For example, for one visit you will spend 20% of the 3-hour visit in light activity (36 min) with the remaining 80% spent sitting (144 min).Conditions will be randomized each week and include:

Activity	Condition 1: 20% time in light intensity	Condition 2: 40% time in light intensity	Condition 3: 60% time in light intensity
Walk (Treadmill) (min)	4.5	9	13.5
Household (Folding Laundry/Dusting/Sweeping) (min/min/min)	1.5/1.5/1.5	3/3/3	4.5/4.5/4.5
Walk (Treadmill) (min)	4.5	9	13.5
Occupational (Standing Work) (min)	4.5	9	13.5
Walk (Treadmill) (min)	4.5	9	13.5
Leisure Time (Playing Cards/Cycling/light Calisthenics) (min/min/min)	1.5/1.5/1.5	3/3/3	4.5/4.5/4.5
Walk (Treadmill) (min)	4.5	9	13.5
Seated (min)	144	108	72

During each of these conditions we will be monitoring the air you breathe by putting a facemask over your nose and mouth. You will be able to breathe feely in and out of the facemask. We will analyze the air you expire for oxygen and carbon dioxide to determine how hard you were working, how much fat and carbohydrate you were

using, and how many calories you were burning. In addition, you will wear a heart rate monitor (a plastic and fabric strap) around your chest that transmits your heart rate (beats/min).

Directly prior to beginning the three hour measurement, you will be asked to consume a liquid meal (8 fl oz Ensure PLUS). This allows us to simulate how the different conditions would affect your blood sugar levels following consuming a meal.

We will collect blood at four separate time points during the condition (one at the start of the condition and one each hour; hour 1, hour 2, hour 3). The blood will be collected from the outside of your selected fingertip. A different fingertip can be used for each finger prick. The total amount of blood removed is small (0.02 teaspoons) and will not be detrimental to your health. We will use the collected blood to measure your glucose level.

Optional: if consent is provided, this will be the time at which pictures may be taken in order to describe what activities were done during the activity protocol during future presentations of the research study. Any photo recordings are an optional consent and not a main component of the research study.

International Physical Activity Questionnaire (approximately 15 minutes):
You will be asked to complete a survey regarding the usual amount of physical activity over the past seven days. There are a total of 27 questions, highlighting different aspects of your day asking what types of activities you may or may not have engaged in. For example: "During the last 7 days how many days did you do moderate activities like carrying light loads, sweeping, washing windows, and raking in the garden or yard." This can be completed during the seated portion of the activity condition.

24-hour Dietary Recall Survey (20 minutes):
You will complete a survey on the computer in the lab asking you questions about all the food and drink you have had over the past day. Questions will consist of information on for what meal the food/drink was consumed (breakfast, lunch, dinner, snack), at what time the food/drink was consumed, and where the food/drink was consumed. This can be completed during the seated portion of the activity condition.

4. Risks and Minimizing Risks

What risks will I face by participating in this study?
The main risk you face by participating in this research study is associated with the body composition test. You will be exposed to a small amount of radiation during

this assessment. The overall effect of radiation on the human body is measured in terms of Roentgen equivalents in man, or "rem," which is a unit of uniform whole body exposure. The amount of radiation you will be exposed to in this study will amount to 0.004 rems. This radiation exposure will be added to your overall lifetime radiation risk. Lifetime radiation risk includes the background radiation people are exposed to naturally, which averages 0.3 rem units per year. In terms of radiation you may get exposed to during medical care, the amount you will receive in this study will be small compared to the amount of radiation received during a routine chest x-ray, which is 0.01 rem units. The risk of harm from this amount of radiation exposure is too small to estimate.

If you rarely engage in any type of active behaviors you may experience muscle soreness from participation in the light intensity activities. All activities are self-paced or relative to your fitness level to detract from any higher intensities.

The blood sampling procedure may cause some localized bruising and/or tenderness of the finger and there is a small risk of infection. A sterile needle will be used for each test. A trained technician will perform the finger prick for blood sampling. The total amount of blood removed is small (0.02 teaspoons) and will not be detrimental to your health. It is possible that more than one stick may be needed to obtain the necessary blood sample. Research staff will minimize the likelihood of multiple sticks by keeping the participant's hands warm and placing the hand below the level of the heart.

The portable metabolic system is a lightweight system that seeks to limit any additional load carried by the participant during daily activities. The portable metabolic system facemask that is worn over your nose and mouth may cause slight discomfort, such as pressure from wear.

The information collected in this study is kept strictly confidential. Only the people directly involved in this study will have access to the information. Your name will never be associated with any of the information collected or the picture we take of you. Your name will be associated with an identification number that which will not allow your information to be traced back to this research study. If photo consent is provided individual faces will be blacked out on all photos used in presentations. However, there is the potential of identification by identifiable markers such as tattoos. The intention of these photos is for use in presentations (such as dissertation defense presentation). We may decide to present what we find to others, or publish our results in scientific journals or at scientific conferences. If this happens, your name will never be associated with any of the data collected, and your identity will always remain strictly confidential. All research data is stored electronically on a password-protected computer as well as in hard copy in a locked cabinet.

As with any research study, there may be additional risks of participating that are unforeseeable or hard to predict.

5. Benefits

Will I receive any benefit from my participation in this study?
Yes, we will provide you with information on your height, weight, and body fat level, as well as a general estimation of how many calories you would burn in a day following the completion of the study.

6. Study Costs and Compensation

Will I be charged anything for participating in this study?
You will not be responsible for any of the costs from taking part in this research study.

Are subjects paid or given anything for being in the study?
You will receive a $25 gift card following completion of the first and second visit and $50 gift card following completion of the third and fourth visit.

7. Confidentiality

What happens to the information collected?
All information collected about you during the course of this study will be kept confidential to the extent permitted by law. We may decide to present what we find to others, or publish our results in scientific journals or at scientific conferences. Only the PI and associated laboratory personnel will have access to the information. However, the Institutional Review Board at UW-Milwaukee or appropriate federal agencies like the Office for Human Research Protections may review this study's records. All the information collected in this study will be stored in Enderis Hall 434 for five years for future use.

With your permission, we may take photos of you participating in this study. The photo may be used in presentations at scientific meetings in order to describe the study. Photos will be stored electronically in the secure server within UWM that is password protected. Electronic data will be stored in a secure server within UWM that is password protected and print data will be stored in the locked file cabinet in the laboratory. Participant names will be removed from the data using black ink within a year of collection once the data are checked for any error. A key that links the ID numbers with names will be stored in a separate file electronically. Only the laboratory members will have access to these data.

8. Alternatives

Are there alternatives to participating in the study?
There are no known alternatives available to you other than not taking part in this study.

9. Voluntary Participation and Withdrawal

What happens if I decide not to be in this study?
Your participation in this study is entirely voluntary. You may choose not to take part in this study. If you decide to take part, you can change your mind later and withdraw from the study. You are free to not answer any questions or withdraw at any time. If you withdrawal from the study after data has been collected, the collected data will be kept for analysis and disposed of properly at the conclusion of the study. Your decision will not change any present or future relationships with the University of Wisconsin Milwaukee. We will use the information collected to that point.

10. Questions

Who do I contact for questions about this study?
For more information about the study or the study procedures or treatments, or to withdraw from the study, contact:

Ann M. Swartz, Ph.D.
Associate Professor
Department of Kinesiology
2400 E. Hartford Ave.
414-229-4242

Who do I contact for questions about my rights or complaints towards my treatment as a research subject?
The Institutional Review Board may ask your name, but all complaints are kept in confidence.

Institutional Review Board
Human Research Protection Program
Department of University Safety and Assurances
University of Wisconsin – Milwaukee
P.O. Box 413
Milwaukee, WI 53201
(414) 229-3173

11. Signatures

Research Subject's Consent to Participate in Research:
To voluntarily agree to take part in this study, you must sign on the line below. If you choose to take part in this study, you may withdraw at any time. You are not giving up any of your legal rights by signing this form. Your signature below indicates that you have read or had read to you this entire consent form, including the risks and benefits, and have had all of your questions answered, and that you are 18 years of age or older.

_____
Printed Name of Subject/ Legally Authorized Representative

_____ _____
Signature of Subject/Legally Authorized Representative Date

Optional Research Subject's Consent to Photo Recording:

It is okay to photograph me while I am in this study and use my photographed data in the research.

Please initial: ___Yes ___No

Principal Investigator (or Designee)
I have given this research subject information on the study that is accurate and sufficient for the subject to fully understand the nature, risks and benefits of the study.

_____ _____
Printed Name of Person Obtaining Consent Study Role

_____ _____
Signature of Person Obtaining Consent Date

Appendix N: Health History Questionnaire: Dose Response between time spent in light intensity physical activity and glucose dynamics in older adults

PROJECT ID	HEALTH HISTORY AND DEMOGRAPHIC QUESTIONNAIRE	CURRENT DATE
_____		_____

Address: _____

City: _____ **ZipCode:** _____

Phone: _____ **Date of Birth:** _____ **Current Age:** _____

Gender (circle one): M F If Female, have you reached menopause? (circle one) Yes No

If YES, at what age? _____

Senior Center Member (circle one): Yes No

Do You Live Alone? (circle one): Yes No

Occupation: _____ **Full Time? (circle one):** Yes No

Marital Status (circle one): Single Married Divorced Widowed

Race (circle ethnicity): White American Indian Asian Hispanic

Black / African American Native Hawaiian / Pacific Islander

Are you taking any prescription or over-the counter medication? (circle one) YES NO

If YES, please indicate the names, reasons, and how long you have been taking the medication below.

Name of Medication Reason for Taking For How Long?

Emergency Contact Information:

Name: _____

Relationship: _____ Phone: _____

Personal Physician Name: _____ **Location:** _____

YOUR PAST HEALTH HISTORY	**FAMILY HEALTH HISTORY**
Circle any of the following medical conditions you have either been diagnosed with or have experienced.	**Circle any of the following medical conditions experienced by any immediate family and indicate who has/had the condition and when (brothers/sisters, children, parents).**
High blood pressure	Stroke
Any heart problems	Blood Clots
Arthritis	Cancer
Diabetes	
Recurring leg pain (not related to arthritis)	
Liver or Kidney Disease	
Any breathing or lung problems	
Ankle swelling (not related to twisting)	
Heart attacks	Stroke
High blood pressure	Early death
High cholesterol	Diabetes
Congenital heart defect	
Heart operations	
Other family illnesses _____	
_____	

YOUR PRESENT HEALTH (SIGNS & SYMPTOMS)

Circle any of the following signs and symptoms you are currently experiencing (within the last year).

Chest pain / discomfort	Cough on exertion
Shortness of breath	Coughing of blood
Heart palpitations	Dizzy spells
Skipped heart beats	Frequent headaches
Heart Attack	Orthopedic / joint problems
Diabetes	Back Pain

Have you been hospitalized in the last year?(circle one) Yes No

Have you ever had your cholesterol measured? (circle one) YES NO If YES, (list value) ____

Do you currently smoke? (circle one) YES NO If YES, what? (circle) Cigarettes Cigars Pipe

How much per day: (circle one) < 0.5 pack 0.5 to 1 pack 1.5 to 2 packs >2 packs

Have you ever quit smoking? (circle one) YES NO If YES, how old were you when you quit?

How many years did you smoke? _____

Do you drink alcoholic beverages? (circle one) YES NO If YES, how many beverages in 1 week? ___

Appendix O: Actigraph Accelerometer Instructions

uwm physical activity and health research lab

Department of Kinesiology

Enderis Hall, Rm. 434 • (414)229-4392

INSTRUCTIONS FOR WEARING THE ACCELEROMETER

- Please wear this unit for 7 consecutive days :_____
- Wear the accelerometer on your right hip, in line with your right knee cap. **Please make sure that the accelerometer is as vertical as possible (not slanting away from or toward your body).
- Wear the accelerometer for all waking hours of the day. It is essential that the accelerometer stays in a specific orientation with **black button facing up**.
- You are not required to press any buttons for the accelerometer. Simply wear it as instructed and return on your next visit.

CURRICULUM VITAE

Whitney A. Welch, M.S.
Doctoral Candidate
wawelch@uwm.edu

Education

Doctor of Philosophy (Ph.D.). (2016). The University of Wisconsin, Milwaukee, College of Health Sciences, Milwaukee, WI. Concentration: Exercise Physiology. Cognate: Public Health.
Dissertation: Evaluation of Light Intensity Physical Activity and Health in Older Adults.

Master of Science (M.S.). (2012). The University of Tennessee. Department of Kinesiology, Recreation, and Sport Studies, Knoxville, TN.
Concentration: Exercise Physiology.
Thesis: Classification accuracy of the wrist-borne GENEA accelerometer during structured activity bouts: a cross-validation study.

Bachelor of Science in Education (B.S.E.). (2010). The University of Tennessee, Department of Kinesiology, Recreation, and Sport Studies, Knoxville, TN. Major: Exercise Science.

Professional Experience

2015-2016 Distinguished Dissertator Fellow, University of Wisconsin, Milwaukee

2014-2015 Distinguished Graduate Student Fellow, University of Wisconsin, Milwaukee

2012-Present Graduate Research Assistant, University of Wisconsin, Milwaukee
Physical Activity & Health Research Laboratory

2014-Present Graduate Research Assistant, University of Wisconsin, Milwaukee
Center for Aging & Translational Research

2014-Present Ad Hoc Lecturer, University of Wisconsin, Milwaukee
Exercise Physiology
Exercise Testing & Prescription
Introduction to Kinesiology

2012- 2014 Graduate Teaching Assistant , University of Wisconsin, Milwaukee
Exercise Physiology

2011- 2012 Graduate Research Assistant, University of Tennessee, Knoxville
Applied Physiology Laboratory

Publications

Published

1. Bassett, D.R., Fitzhugh, E.C., Heath, G.W., Erwin, P.C., Frederick, G.M., Wolff, D.L., **Welch, W.A.** & Stout, A.B. (2013). Estimated energy expenditure for school-based policies and active living. *American Journal of Preventive Medicine.* 44(2): 108-113. PMID: 23332325

2. **Welch, W.A.,** Bassett, D.R., Thompson, D.L., Freedson, P.S., Staudenmayer, J.W., John, D., Steeves, J.A., Conger, S.A., Ceaser, T., Howe, C.A., Sasaki, J.E. & Fitzhugh, E.C. (2013) Classification accuracy of the wrist-worn GENEA accelerometer. *Medicine & Science in Sports & Exercise.* 45(10): 2012-2019. PMID:23584403

3. Bassett, D.R., Fitzhugh, E.C., Heath, G.W., Erwin, P.C., Frederick, G.M., Wolff, D.L. & **Welch, W.A.** (2013). Policies to increase youth physical activity in school and community settings. *President's Council on Fitness, Sports, and Nutrition: Research Digest.* 14(1): 1-10.

4. **Welch, W.A.,** Bassett, D.R., Freedson, P.S., John, D., Steeves, J.A., Conger, S.A., Ceaser, T., Howe, C.A., Sasaki, J.E. (2014) Cross-validation of GENEA accelerometer waist cut-points. *Medicine & Science in Sports & Exercise.* 46(9): 1825-1830. PMID: 24496118

5. Swartz, A.M., Rote, A.E., Hart, T.E., **Welch, W.A.,** & Strath, S.J. (2014) Prompts to disrupt sitting time and increase physical activity at work, 2011-2012. *Preventing Chronic Disease.* 11:130318. DOI: http://dx.doi.org/10.5888/pcd11.130318. PMID: 24784909

6. Swartz, A.M., Rote, A.E., Cho, Y., **Welch, W.A.** & Strath, S.J. (2014) Responsiveness of motion sensors to detect change in sedentary and physical activity behaviour. *British Journal of Sports Medicine.* 48(13): 1043-1047. PMID: 24825854

7. **Welch, W.A**., Strath, S.J. & Swartz, A.M. (2015) Congruent validity and reliability of two metabolic systems to measure resting metabolic rate. *International Journal of Sports Medicine.* 36: 414-418. PMID: 25700097

8. Strath, S.J., Kate, R.J. Keenan, K.G., **Welch, W.A**., & Swartz, A.M. (2015) Ngram time series model to predict activity type and energy expenditure from wrist, hip and ankle accelerometers: implications of age. *Physiological Measurement.* 36(11):2335-2351. PMID: 26449155

9. Kate, R.J., Swartz, A.M., **Welch, W.A.,** Strath, S.J. (2016) Comparative evaluation of features and techniques for identifying activity type and estimating energy cost from accelerometer data. *Physiological Measurement.* 37(3): 360-379. PMID: 26862679

10. Swartz, A.M., Cho, Y., **Welch, W.A.,** Strath, S.J. (2016) Movement Quality Discordance between healthy and non-healthy U.S. adults. *Plos ONE.* PMID: 26918868

11. **Welch, W.A**., Swartz, A.M., Cho, C., & Strath, S.J. (2016) Accuracy of direct observation to assess physical activity in older adults. *Journal of Aging and Physical Activity.* EPub Ahead of Print. PMID: 26964757

In Review

12. Swartz, A.M., Miller, N.E., Cho, Y., **Welch, W.A**. & Strath, S.J. (In Review) A prospective examination of the impact of high levels of exercise training on sedentary behavior. *International Journal of Sports Medicine.*

13. **Welch, W.A**., Bassett, D.R., Freedson, P.S., Springer C., John, D., Steeves, J.A., Conger, S.A., Ceaser, T., Howe, C.A., Sasaki, J.E. (In Review) Comparability of activity counts from tri-axial accelerometers on the ankle, wrist, and waist during structured activities. *Research Quarterly.*

14. Swartz, A.M., Cho, C.C., **Welch, W.A.,** Widlansky, M.E., Strath, S.J. (In Review) Increases in walking are primarily moderate intensity in response to a 10,000 step per day pedometer intervention: Results of two randomized controlled trials. *International Journal of Behavioral Nutrition and Physical Activity.*

15. Tuttle, M., **Welch, W.A.**, Swartz, A.M., Harber, M., Montoye, A.H.K., Kaminsky, L.A. (In Review) Reference values for body fat percentage using GE Lunar Prodigy and iDXA dual energy x-ray absorptiometry systems. *Medicine & Science in Sport & Exercise.*

16. **Welch, W.A.,** Strath, S.J. & Swartz, A.M. (In Review) Light Intensity Physical Activity: A Systematic Review. *Sports Medicine.*

17. Bernstein, R., **Welch W.**, Schneider, R., Dressel, A., DeNomie, M., Kusch J., Sosa, M. (In Review) Biking for Health: Results of a pilot randomized

controlled trial examining the fitness, health, and behavioral impact of a bicycling intervention on lower-income adults. *Journal of Physical Activity and Health.*

18. Dressel, A., Schneider, R., DeNomie, M., Kusch, J., **Welch, W.,** Sosa, M., Yeldell, S., Maida, T., Binder, J., Holt, K., Bernstein, R. (In Review) Translational science research: learning how to improve traditional research methods for community-engaged studies. *Progress in Community Health Partnerships: Research, Education, and Action.*

In Preparation

19. **Welch, W.A.,** Strath, A.M., Bassett, D.R., Schueller, D., Miller, N.E., & Swartz, A.M. (In Preparation) Relationship of total activity counts per day to physical activity energy expenditure: Hip and wrist accelerometers. *Physiological Measurement.*

20. Bassett, D.R., Freedson, P.S., **Welch, W.A**., & John, D. (In Preparation) Influence of Age on Activity-Related Energy Expenditure in Adults 20-60 Years of Age. *Medicine & Science in Sports & Exercise.*

21. Schneider, R., Bernstein, R., Dressel, A., DeNomie, M., Kusch, J., **Welch, W.,** Sosa, M., Yeldell, S., Maida, T. (In Preparation) Biking for Health: Summary of self-reported bicycle activity and barriers to bicycling. *Transportation Research Part F: Traffic Psychology & Behavior.*

22. **Welch, W.A.,** Strath, S.J., Greenleaf, C., Walker, R., Brondino, M., Nehls, D., Swartz, A.M. (In Preparation) Contextual analysis of light intensity physical activity in older adults.

Book Chapters

Swartz A.M. and **Welch, W.A.** *Approaches to Decrease Sedentary Behavior Among the Elderly*. Sedentary Behavior Epidemiology. Springer. New York, NY. (Invited)

Presentations

National/International

1. **Welch, W.A.,** Bassett, D.R., Thompson, D.L., Freedson, P.S., Staudenmayer, J.W., John, D., Steeves, J.A., Conger, S.A., Ceaser, T., Howe, C.A., Sasaki, J.E. & Fitzhugh, E.C. (2013). Classification accuracy of the wrist-worn GENEA accelerometer during structured activity bouts. *Southeast American College of*

Sports Medicine, Greeneville, SC, February 16. (Poster presentation based on original research, peer reviewed, academic audience).

2. **Welch, W.A.,** Bassett, D.R., Thompson, D.L., Freedson, P.S., Staudenmayer, J.W., John, D., Steeves, J.A., Conger, S.A., Ceaser, T., Howe, C.A., Sasaki, J.E. & Fitzhugh, E.C. (2013). Classification accuracy of the wrist-worn GENEA accelerometer during structured activity bouts. *American College of Sports Medicine National Meeting,* Indianapolis, IN, May 31. (Thematic presentation based on original research, peer reviewed, academic audience).

3. **Welch, W.A.,** Bassett, D.R., Freedson, P.S., Staudenmayer, J.W., John, D., Steeves, J.A., Conger, S.A., Ceaser, T., Howe, C.A., & Sasaki, J.E. (2013). A cross-validation study of the GENEA accelerometer waist cut-points. *International Conference on Ambulatory Monitoring of Physical Activity and Movement,* Amherst, MA. June 17. (Poster presentation based on original research, peer reviewed, academic audience).

4. Swartz, A.M., Rote, A., Thielke, N., **Welch, W.,** Strath, S.J. (2013). Congruency of motion sensors to detect change following a sedentary behavior intervention. *International Conference on Ambulatory Monitoring of Physical Activity and Movement,* Amherst, MA. June 17. (Oral slide presentation based on original research, peer reviewed, academic audience).

5. **Welch, W.A.,** Strath, S.J., Koebert, M.L., Winker, K.N., & Swartz, A.M. (2014) Congruent validity and reliability of two metabolic systems to measure resting metabolic rate. *International Society of Behavioral Nutrition and Physical Activity Annual Meeting,* San Diego, CA. May 21. (Poster presentation based on original research, peer reviewed, academic audience).

6. **Welch, W.A**., Strath, S.J., Swartz, A.M. (2014). Comparison of wrist-worn accelerometer output based on handedness. *American College of Sports Medicine National Meeting,* Orlando, FL. May 30. (Poster presentation based on original research, peer reviewed, academic audience).

7. Swartz, A.M., Miller, N.E., **Welch, W.A.,** Cho, Y.I., & Strath, S.J. (2014) Objective Assessment of Sedentary Behavior during and after Prolonged, Intensive Aerobic Exercise Training. *American College of Sports Medicine* annual meeting. Orlando, FL May 29. (Poster presentation based on original research, peer reviewed, academic audience).

8. **Welch, W.A.,** Swartz, A.M., & Strath, S.J. (2015) Accuracy of direct observation to assess physical activity in older adults. *American College of Sports Medicine* annual meeting. San Diego, CA May 27. (Poster presentation based on original research, peer reviewed, academic audience).

9. Bassett, D.R., Freedson, P.S., **Welch, W.A.,** & John, D. (2015) Influence of Age on Activity-Related Energy Expenditure in Adults 20-60 Years of Age. *American College of Sports Medicine* annual meeting. San Diego, CA May 28. (Slide presentation based on original research, peer reviewed, academic audience).

10. Strath, S.J., Cho, Y.I., **Welch, W.A.**, Rowley, T.W., Miller, N.E., & Swartz, A.M. (2015) Simulation of accelerometer data reduction choices on sample size and select physical activity and sedentary outcomes in older adults. *International Conference on Ambulatory Monitoring of Physical Activity and Movement,* Limerick, Ireland. June 10. (Poster presentation based on original research, peer reviewed, academic audience).

11. Swartz, A.M., Widlansky, M.E., Cho, C.C., Miller, N.E., **Welch, W.A**., Strath, S.J. (2015) Characterizing physical activity and sedentary behavior change in response to a step goal. *International Conference on Ambulatory Monitoring of Physical Activity and Movement,* Limerick, Ireland. June 11. (Poster presentation based on original research, peer reviewed, academic audience).

12. **Welch, W.A**., Strath, S.J., Bassett, D.R., Miller, N.E., Swartz, A.M. (2015) A comparison of wrist and hip accelerometer counts to measured total daily physical activity energy expenditure. *International Conference on Ambulatory Monitoring of Physical Activity and Movement,* Limerick, Ireland. June 10. (Poster presentation based on original research, peer reviewed, academic audience).

13. Tuttle, M., **Welch, W.A.**, Swartz, A.M., Harber, M., Montoye, A.H.K., Kaminsky, L.A. (2016) Reference values for body fat percentage using GE Lunar Prodigy and iDXA dual energy x-ray absorptiometry systems. *American College of Sports Medicine* annual meeting. Boston, MA. (Poster presentation based on original research, peer reviewed, academic audience).

14. Strath, S.J., Swartz, A.M., Hyngstrom, A., Keenan, K.G., Rowley, T.W., Miller, N.E., **Welch, W.A.,** Cho, C., Staudenmayer, J. (2016) Validity of accelerometer methods to estimate activity energy cost in adults with and without functional limitations. *American College of Sports Medicine* annual meeting. Boston, MA. (Slide presentation based on original research, peer reviewed, academic audience).

15. Swartz A.M., Cho, Y.I., **Welch, W.A.**, Strath, S.J. (2016) Movement Quality Discordance between healthy and non-healthy U.S. adults. *American College of Sports Medicine* annual meeting. Boston, MA. (Poster presentation based on original research, peer reviewed, academic audience).

16. Rowley, T.W., Swartz, A.M., Staudenmayer, J., Keenan, K., Miller, N.E., **Welch, W.A.,** Cho, C.C., Strath, S.J. (2016) Energy cost of slow and normal gait speed

in adults with and without lower-body impairments. *American College of Sports Medicine* annual meeting. Boston, MA. (Poster presentation based on original research, peer reviewed, academic audience).

17. **Welch, W.A.,** Alexander, N., Swartz, A.M., Strath, S.J. (2016) Individualized cutpoint analyses may better estimate physical activity intensity in older adults with Type 2 Diabetes Mellitus. *American College of Sports Medicine* annual meeting. Boston, MA. June 1. (Thematic presentation based on original research, peer reviewed, academic audience).

Local

1. **Welch, W.A.,** Strath, S.J., Miller, N.E., Thielke, N., Rote, A.E., & Swartz, A.M. Physical activity and sedentary behavior pre- and post-marathon. (2013) *University of Wisconsin-Milwaukee College of Health Sciences Spring Research Symposium,* Milwaukee, WI. May 3.

2. **Welch, W.A**., Strath, S.J., & Swartz, A.M. (2013) Comparison of wrist-worn accelerometer output based on handedness. *University of Wisconsin-Milwaukee College of Health Sciences Fall Research Symposium,* Milwaukee, WI. December 6.

3. **Welch, W.A.,** Strath, S.J., Koebert, M.L., Winker, K.N., & Swartz, A.M. (2014) Congruent validity and reliability of two metabolic systems to measure resting metabolic rate. *University of Wisconsin-Milwaukee College of Health Sciences Spring Research Symposium,* Milwaukee, WI. May 2.

4. Winker, K.N., **Welch, W.A.,** Russo, M.T., Palya, A.J., Koebert, M.L., & Strath, S.J. (2014) The effect of point-of-decision prompts on stair use in university students. *University of Wisconsin-Milwaukee College of Health Sciences Spring Research Symposium,* Milwaukee, WI, May 2.

5. Kotvis, J., **Welch, W.A.,** Strath, S.J., Swartz, A.M. (2015) Accelerometer counts during structured and free-living sedentary behavior. *University of Wisconsin-Milwaukee College of Health Sciences Spring Research Symposium,* Milwaukee, WI, May 1.

6. Rowley, T.W., **Welch, W.A.,** Strath, S.J., Winker, K.N., Russo, M.T., Swartz, A.M. (2015) A comparison of two interventions to decrease sedentary behavior in healthy older adults. *University of Wisconsin-Milwaukee College of Health Sciences Spring Research Symposium,* Milwaukee, WI, May 1.

7. **Welch, W.A.,** Swartz, A.M., & Strath, S.J. (2015) Accuracy of direct observation to assess physical activity in older adults. *University of*

Wisconsin-Milwaukee College of Health Sciences Spring Research Symposium, Milwaukee, WI, May 1.

Grants

1. Bernstein, R. (PI), Schneider, R., Dressel, A., **Welch, W**., Holt, K., Maida, T. Biking for health: a pilot study of a bicycling intervention to improve physical activity in inactive adults in an urban setting. Clinical & Translational Science Institute of Southeast Wisconsin. $49,996.00. 2015.

2. **Welch, W.A.** & Swartz, A.M. Dose-Response of time spent in light intensity physical activity and glucose dynamics in older adults. Center for Aging and Translational Research Pilot Grant. $3,000.00. 2015.

TEACHING

Course Titles of Classes Taught:

KNS 200 Lecture: Introduction to Kinesiology
Fall 2014: 105 students
Fall 2015: 130 students
KNS 330 Lecture: Exercise Physiology
Summer 2014: 10 students
Spring 2015: 23 students
KNS 330 Laboratory: Exercise Physiology Laboratory
Fall 2012: 24 students
Spring 2013: 25 students
Summer 2013: 18 students
Fall 2013: 38 students
Spring 2014: 34 students
KNS 430 Lecture: Exercise Testing and Prescription
Spring 2016: 13 students

Guest Lectures/ Invited Speaker

Welch, W.A. (2013). Exercise Physiology of Moderate Intensity Activity. UWM Walks; Best Places to Work Initiative. University of Wisconsin-Milwaukee. September 16.

Welch, W.A. (2013). Physiology of Physical Activity: A History. Department of Kinesiology KIN 200. The University of Wisconsin-Milwaukee. October 22.

Welch, W.A. (2014). Cardiovascular Health and Exercise. *Departments of Biomedical Sciences & Kinesiology* NUTR 240. The University of Wisconsin-Milwaukee. March 3.

Welch, W.A. (2014). Cardiorespiratory Training Principles and Adaptations. Department of Kinesiology KNS 330. The University of Wisconsin-Milwaukee. April 1.

Welch, W.A. (2015, 2016). Cardiovascular Health and Exercise. *Departments of Biomedical Sciences & Kinesiology* NUTR 240. The University of Wisconsin-Milwaukee.

Mentoring Activities

Undergraduate Students

Joseph Kotvis (2013 – present)

Project: Accelerometer counts during structured and free-living sedentary behavior.

David Nehls (2015-present)

Masters Students

Kimberly Winker (2012-2014)

Project: A comparison of two interventions to decrease sedentary behavior in healthy older adults.

SERVICE

Exercise Physiology Search & Screen Committee (2013-2014) University of Wisconsin-Milwaukee.
Health and Wellness Research Committee Consultant, Wisconsin Physical Therapy Association
Outreach Committee, International Society for the Measurement of Physical Behaviour

Professional Memberships

American College of Sports Medicine (2010- present)
International Society for the Measurement of Physical Behaviour (2015-present)
International Society of Behavioral Nutrition and Physical Activity (2014-present)
Southeast American College of Sports Medicine (2010- 2014)

Ad-Hoc Manuscript Reviewer

Medicine & Science in Sport & Exercise
Journal of Physical Activity and Health
Physiological Measurement
Pediatric Exercise Science
Journal of Sport Sciences
Journal of Science and Medicine in Sport
IEEE Transactions on Biomedical Engineering
Scandinavian Journal of Medicine and Science in Sports

Awards

Chancellor's Graduate Student Award, University of Wisconsin-Milwaukee (2013-2014)

Distinguished Graduate Student Fellowship, University of Wisconsin-Milwaukee (2014-2015)

Distinguished Dissertator Fellowship, University of Wisconsin-Milwaukee (2015-2016)

American Kinesiology Association, National Doctoral Scholar (2016)