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Low-Intensity Physical Activity and Cardiometabolic Risk Factors Among Older Adults with Multiple Chronic Conditions

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DEDICATION

I dedicate this thesis to my parents, Weidong Li and Lisha Zhang. This thesis as well as my journey of my life would not be possible without your support and encouragement.

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ABSTRACT

Introduction

Cardiovascular disease (CVD) is the leading cause of death among older adults in the Unites States and is driven largely by cardiometabolic risk factors including elevated blood pressure and blood glucose. Studies have found the protective effect of moderate intensity physical activity (MIPA) and vigorous intensity physical activity (VIPA) on cardiometabolic risk factor; however, the association between light physical activity (LIPA) and cardiometabolic risk factor among older adults is not clear.

Objectives

1). Examine the association between LIPA and cardiometabolic risk factors.

2). Examine whether the association between LIPA and cardiometabolic risk factor is moderated by multiple chronic conditions.

Methods

Data from the Health and Retirement Study (HRS) were used for this study. We ascertained 2006 and 2008 HRS data from the Public Use Dataset, the RAND HRS Data File (Version N), and the HRS Biomarker Dataset. There were11890 participants aged 50 or older for cross-sectional analysis. Physical activity was converted to metabolic equivalent of tasks (METS) and outcome variables (systolic and diastolic blood pressure and HbA1c) were measured objectively. Mean levels of blood pressure and HbA1c were compared across physical activity intensity groups. Separate linear regression models

were used to examine the association between LIPA and cardiometabolic risks adjusting for potential sociodemographic, behavioral, and clinical confounders.

Results

In the final study sample, 28.75% were sedentary, 9.46% regularly engaged in LIPA, 34.68% engaged in MIPA, and 27.12% engaged in VIPA. We did not find significant associations between LIPA and systolic blood pressure (*B* = 0.235; 95% confidence interval (CI), -1.127, 1.597), diastolic blood pressure (*B* = -0.167; 95% CI, -0.954, 0.621), or HbA1c levels (*B* = -0.009; 95% CI, -0.049, 0.066). The average HbA1c was significantly lower only among individuals who engaged in MIPA (*B* = -0.097; 95% CI, -0.174, -0.020) and MIPA (*B* = -0.140; 95% CI, -0.218, -0.063) in comparison to individuals who were categorized as in sedentary group

Conclusion

The findings from our study do not suggest that LIPA is independently associated with lower cardiometabolic risk factors among older adults. Associations between physical activity intensity and cardiometabolic risk factors among older adults with multiple chronic conditions need to be verified in studies using more objective measurement of physical activity.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

CVD .... Cardiovascular Disease

HS .... High School

LIPA .... Light Intensity Physical Activity

MCC .... Multiple Chronic Conditions

MIPA .... Moderate Intensity Physical Activity

MET .... Metabolic Equivalent

PA .... Physical Activity

VIPA .... Vigorous Intensity Physical Activity

CHAPTER 1

INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death in the Unites States and among the world, and it is driven largely by cardiometabolic risk factors including elevated blood pressure and blood glucose levels. Studies have established that regular physical activity can help maintain cardiovascular health and prevent poor health outcomes and complications from stroke, hypertension, and type 2 diabetes mellitus (Dustan et al 2011, Wedenl-Vos et al, 2004, Helmrich et al 1991, Hu et al 2001, Paffenbarger et al 1986). Epidemiologic evidence has shown that cardiometabolic risk factors, namely blood pressure and blood glucose can be improved by engaging in regular physical activity (Lyden et al 2015, Wijsman et al 2013, Young et al 2014).

Older adults are the most rapidly growing population in the United States (UNFPA 2012). Older adults are also reported to be the age group that has the least physical activity participation (Jefferis et al 2014, Loprinzi et al 2015). The 2008 Physical Activity Guidelines for Americans recommended that older adults need at least 150 minutes of moderate-intensity aerobic activity every week and muscle-strengthening activities on 2 or more days a week, or 75 minutes of vigorous intensity aerobic activity and muscle strengthening activities on 2 or more days a week (US. DHHS, 2008) However, Centers for Disease Control and Prevention (CDC) reported that less than half of the adults aged 65 years and older in the United States meet this guideline. Some studies have suggested that the low percentage of older adults meeting physical activity guidelines was related to concerns regarding their health status and functional limitation of mobility due to aging (Gardener et al 2006, Burton et al 2012, Li et al 2009, Loprinzi et al 2013). However, the benefit of low intensity physical activity is not entirely clear and the recommendation of such physical activity is not included in the current guidelines. More evidence is needed to determine the health impact of low intensity physical activity among older adults, particularly among those with multiple chronic conditions. To address these gaps in the literature we will conduct a cross-sectional study to examine the association between low intensity physical activity and two cardiometabolic risk factors (e.g. HbA1c and blood pressure) among older adults with multiple chronic conditions by using Health and Retirement Study (HRS) data set.

To address this objective we will:

1). Examine the association between light intensity physical activity intensity and cardiometabolic risk factors (i.e., HbA1c, systolic blood pressure, and diastolic blood pressure) among older adults.

Hypothesis: It is hypothesized that individuals who engage in light, moderate and vigorous intensity physical activity will have a better control of HbA1c, systolic blood pressure and diastolic blood pressure compared to sedentary individuals who hardly ever or never engage in any (light, moderate and vigorous) physical activity.

2). Examine whether the association between light, moderate and vigorous physical activity and cardiometabolic risk factor control (i.e., HbA1c, systolic blood pressure, diastolic blood pressure) is moderated by multiple chronic conditions.

Hypothesis: It is hypothesized that among people aged 50 and above with multiple chronic conditions, individuals who engaged in light intensity physical activity would have a better control of cardiometabolic risk factors comparing to those who are physically inactive.

CHAPTER 2

LITERATURE REVIEW

Physical activity guidelines and older adults

Since the publication of first edition of the American College of Sports Medicine Sports Medicine (ACSM) Position Stand "Exercise and Physical Activity for Older Adults," studies have shown the positive association between regular physical activity and health benefits among older adults. ACSM and American Heart Association (AHA) published physical activity guidelines for older adults in 2007 (Nelson ME et al, 2007). The College recommended the important instructions on encouraging older adults to engage in physical activity to achieve health benefits. They recommended a widespread exercise program with the purpose of improvement in muscle strength, endurance, body flexibility and balance of older adults. The 2007 ACSM/AHA guideline suggested that to reach the exercise goal of aerobic activity, older adults should engage in at least 5 day/week for moderate intensity (such as brisk walking) at 5 to 6 on a 10-point scale of intensity, or at least 3 day/week for vigorous activity (such as jogging and running) at 7-8 on a 10-point scale of intensity, with accumulated duration no less than 30 min/day of moderate-intensity activity or 20 min/day of vigorous-intensity activity; to achieve the improvement of muscle-strengthening training, older adults should engage in 8-10 exercises involving the major muscle groups (legs, hips, back, abdomen, chest, shoulders, and arms) with 10-15 repetitions on at least 2 day/week, no less than 2 day/week flexibility and balance enhancement training.

Physical activity levels are reported to be low in older American adults. (Troiano RP et al 2008, Ashe MC et al 2009). Older adults achieving the ACSM and AHA recommendations declines with increasing age. Some researchers have suggest that older adults are less likely to meet the moderate to vigorous physical activity guidelines because of their physical healthy condition or worry on getting injured when physically active (Cardinal BJ et al 2000, Li KK et al 2009).

Older adults may be more likely to engage in light intensity physical activities such as casual walking, dancing slowly, light yard work and housework. (Burton NW et al 2012, Washburn RA et al 2000) Recent studies have demonstrated a positive association between moderate to vigorous intensity physical activity and general health rating, body mass index and emotional health among older adults (Loprinzi et al, 2015, Tucker-Seeley et al, 2009). However, whether light intensity physical activity can work independently as assistant of cardiometabolic risk factor control is still unclear. In addition, formal guidelines for light-intensity physical activity currently do not exist for older adults. It is possible that evidence demonstrating that light intensity physical activity may play a role in improving and maintaining the health of older adults may require a reevaluation of the current recommendations for older adults.

The importance of light intensity physical activity may be underscored with more research on the benefit of such physical activity for older adults. However, the data on the role of light-physical activity among older adults with multiple chronic conditions is limited. It is possible that such research may serve as the evidence-base for future physical activity guidelines to incorporate light intensity physical activity recommendations for older adults with multi-morbidity.

Physical activity and cardiometabolic risk

The 2007 AHA/ACSM recommendation stands that meeting the recommended physical activity, can enhance the important health benefits among older adults. In addition, the 2008 Physical Activity Guidelines by U.S. Department of Health and Human Services confirmed that regular physical activity helps reduce the risk of many adverse health outcomes. Cardiometabolic risk factors include diabetes, blood pressure, total cholesterol, and obesity). Cardiometabolic risk factors are a major cause of disability and mortality among the U.S. population, especially among older adults. (Pescatello et al 1999) Studies have found that habitual physical activity reduces cardiometabolic risk factors among all age groups. (Pescatello et al 1999, LaMonte et al 2006). Studies show that moderate to vigorous activity is associated with protective effect of cardiometabolic risk factors such as blood glucose. (Jung et al 2015, Patel et al 2013, Pahor et al 2014, Assah et al, 2008). In the later Recommendations on Quantity and Quality of Exercise, the ACSM further emphasized the cardiovascular benefits from engaging in moderate to vigorous intensity physical activity (Garber CE et al 2011). However, recently, there have been more studies recommending that light intensity, are more acceptable and have beneficial to the control of cardiometabolic risk factors in older adults. (Loprinzi et al 2015, Healy et al 2008, Gando et al, 2010)

Multiple Chronic Conditions

Multiple chronic conditions or multimorbidity, usually defined as the coexistence of two or more chronic conditions, has become widely prevalent over the past decades. (Salive et al 2013) In the United States, about 50% of adults aged 50-70 live under the burden of two or more ongoing chronic health conditions. These conditions are associated with increased overall mortality and morbidity and disease complications. (Barnett K 2012, Machline et al 2013, Mercer et al 2009) Multiple chronic conditions may be an intermediary of physical activity. People with mobility impairment may be limited in physical activity due to the difficulty of carrying out physical movements. (Freedman et al, 2002, Hung et al 2011) On the other hand, studies have shown that engaging in physical activity help prevent and control multiple chronic conditions and mobility impairment among older adults (Cimarras-Otal C et al, 2014, Fleischman et al, 2015). However, whether the intensity of physical activity has to be moderate or vigorous remains uncertain.

Physical Activity Measurement

Physical activity measurement can be generally collected via objective and self-report methods. Objective methods are accurate in assessing physical activity patterns, intensity, and duration. Common objective physical activity methods include calorimetry, direct observation, pedometers, accelerometers, heart rate monitoring, and other new technologies. Objective measurements are more accurate and validate comparing to subjective measurements, and most of them can provide both quantitative and qualitative information by software calculation. Although objective methods to measure physical activity are increasing in use, self-reported measures are more widely used in large-scale population-based epidemiologic studies. Compared to self-report, especially in studies with large population, it is relatively more expensive to use objective methods. Also, the use of objective methods makes it difficult to distinguish between certain types of activities. (Lee IM et al, 2014) For example, objective measures do not differentiate leisure time activity versus activity for gym workout and exercise. (Hekler EB et al, 2012, Warms C, 2006, Arnardottir NY et al, 2013, Falck RS et al, 2015).

Physical activity diary and exercise log are two relatively accurate self-reported methods, but they bring too much research burden. Currently the most common self-report method for collecting physical activity is still by questionnaire (Warms C, 2006). However, there is great variation in the type of information that is collected and how questions are asked. For example, studies may focus on different aspects of physical activity thus have different weight on questions about physical activity types, durations, frequencies and intensities. Concerns about the validity of self-reported questionnaires specifically related to response bias (i.e. recall bias and over-reporting bias). For example, some studies have demonstrated that self-reported questionnaires often overestimated the true physical activity levels. (Chinapaw MJ et al, 2009, Tudor-Locke CE et al, 2001) However, it is still widely used due to its low participant burden, less cost and the possibility of assessing average long-term patterns. (Warms C et al, 2006, Falck RS et al, Arnardottir NY, et al, 2013, Forsen L et al, 2010) Other self-reported methods include physical activity records or diaries and short-term recalls. Physical activity records or diaries collect detailed information on physical activity type, duration, and intensity by the participant. These methods are subject to less recall bias then self-reported questionnaires, but have limited utility due to their time cost, high participant burden and high research burden. (Warm C, 2006). To increase the validity of such self-reported methods, researchers may conduct unannounced phone calls and ask participants to recall details of physical activity in the past certain time. However, this method requires participants to be cognitive and ability to recall and estimate.

Falck (Falck RS et al, 2015), Warms (Warms C et al, 2006), and Peter (Peter WF et al 2015) have suggested that self-reported questionnaire and objective measurement such as pedometers and accelerometers should be combined to measure physical activity among older adults and people with functional limitation and chronic diseases. However, the use of questionnaires for the collection of self-report physical activity remains a valuable method in epidemiologic studies.

CHAPTER 3

METHODS

Data Source

Data for this study is from the Health and Retirement Study (HRS): the 2006 and 2008 wave, and the RAND HRS Data File for 2006 and 2008 (a cleaned and processed HRS dataset with consistent variable names). HRS is a national longitudinal survey of U.S. adults aged 50 years and older. Enrollment in the study began in 1992 and is ongoing. Data on physical health and functioning, disability, socioeconomic characters, and health care expenditures is collected every two years. The study is sponsored by the National Institute on Aging and conducted by the Institute for Social Research at the University of Michigan. (Juster et al 1995) The response rate was 81.4% in 1992 and was between 85% and 90% in the following waves (Heeringa & Connor, 1995; Juster & Suzman, 1995). Detailed information concerning the sample design, recruitment, response rates and measurement validation are discussed extensively elsewhere (Heeringa & Connor, 1995; Juster & Suzman, 1995). Sampling weights are provided by HRS datasets with the oversample of African American, Hispanic, and residents in Florida. (Simpson et al, 2014.)

In 2006 and 2008 HRS initiated an Enhanced Face-to Face Interview with a leave-behind questionnaire and the collection of biomarkers. For both of these waves, biomarker data were collected from a randomly selected subsample of the population. Half of the 2006 sample was randomly selected to provide biomarkers and in 2008 the other half was preselected to provide biomarker data. We pooled the 6735 observations from the 2006 dataset, and 6329 from the 2008 dataset, for a total of 13064 observations.

Study Population

The final analytic sample was generated from the pooled 2006 and 2008 dataset. Individuals who were younger than 50 (n=246) and self-reported race/ethnicity as other (n=257, frequency less than 2.0%) were excluded. In addition, people missing all three outcome variables (systolic blood pressure, diastolic blood pressure and HbA1c; n=18), or missing light intensity physical activity (n=653) were excluded, yielding 11890 for out cross-sectional analysis.

Measurement of Variable

Exposure Variable

Light intensity physical activity (LIPA), the main exposure of interest, was collected by self-report from participants via questionnaire. To ascertain level of physical activity participants were asked three questions related to vigorous, moderate, and mild levels of physical activity intensity. The following questions were used to assess the three levels, respectively: “How often do you take part in sports or activities that are vigorous, such as running or jogging, swimming, cycling, aerobics or gym workout, tennis, or digging with a spade or shovel?”; “How often do you take part in sports or activities that are moderately energetic such as, gardening, cleaning the car, walking at a moderate pace, dancing, floor or stretching exercises?” and “How often do you take part in sports or activities that are mildly energetic, such as vacuuming, laundry, home repairs?” Response categories for the three questions were: everyday, more than once a week; once a week, one to three times a month, or hardly ever or never.

Based on previous studies (Umstattd Meyer MR et al, 2015, Latham K et al, 2015, Tucker-Seeley et al, 2012, He et al, 2005) and our sample distribution, the frequencies “everyday” and “more than once a week” were combined as one category of “more than once a week”, then individual responses to the questions were weighted by intensity using an average metabolic equivalent (MET) calculation. For vigorous activity, the response categories were coded as: 0= “hardly ever or never”; 2= “1 to 3 times per month”; 6= “once per week”; 12= “more than once per week”. For moderate physical activity, the responses were coded as: 0= “hardly ever or never”; 1= “1-3 times per month”; 3= “once per week”; 6= “more than once per week”. For light physical activity, the response categories were coded as: 0= “hardly ever or never”; 0.5= “1 to 3 times per month”; 1= “once per week”; and 3= “more than once per week”. The scores were summed for all three intensity levels of physical activity and ranged from 0 to 21. The thresholds used to determine physical activity intensity were: sedentary group (< 1.5); light intensity physical activity (≥1.5 – 3.0); moderate physical activity (>3.0 – 6.0); and vigorous physical activity (≥6.0). These cut points were based upon established MET thresholds (Ainsworth et al, 2012). We used the cut points to reduce estimation error and increase the comparability of physical activity intensity across other studies (Ainsworth et al, 2012).

Outcome Variables

Two cardiometabolic risk factors that have strong associations with CVD were assessed: glycosylated hemoglobin (HbA1c) and blood pressure. HbA1c was measured as a continuous variable and was collected using dried blood spot technique. In 2006, the assayed HbA1C was sorted and processed by Biosafe Laboratories. In 2008, HbA1C assays were performed by Biosafe and FlexSite companies.

Blood pressure was measured and assessed separately for systolic blood pressure and diastolic blood pressure and used as a continuous variable. Standard procedures, previously described in details (Crimmins et al, 2008), were used to collect blood pressure. Briefly, both systolic and diastolic blood pressure was measured as the average of three measurements. The participants were told to sit down with both feet on the floor and their left arm comfortably supported with the palm facing up. The cuff was directly contact with the participant's skin with the air tube went down the middle of the participant's arm and the bottom of the cuff nearly half inch above the elbow.

Confounders/ Covariates

Demographic characteristics (i.e., age, gender, race/ethnicity, marital status, education levels, health insurance status, and annual household income), behavioral lifestyle (i.e., BMI, current smoking status), and clinical factors (i.e., self-rated health status, and functional limitation) previously identified as confounders in prior studies were included as confounders in the present study.

Age was collected as a continuous variable and included in the analyses as a continuous variable.

Gender was categorized as "male" and "female".

Race and ethnicity was collected using two questions: "Do you consider yourself primarily White or Caucasian, Black or African America, American Indian, or Asian, or something else", and "Do you consider yourself Hispanic or Latino?" The following mutually exclusive categories were created based on the responses to the questions: "nonwhite", "non-Hispanic black" and "Hispanic." Individuals reporting other racial/ethnic groups were excluded from the analysis.

Marital status was collected by acquiring marital status of the participant in 2006 and 2008 wave, which were described as "married", "married, spouse absent", "partnered", "separated" "divorced", "divorced/separated" "widowed", and "never married". This variable was categorized as "married or partnered (married, married, spouse absent and partnered)" and "unmarried or separated (separated, divorced, divorced/separated, widowed and never married)".

Education status was acquired by the years of education that the participant had finished. In HRS, the education status was coded as "less than high school", "GED", "High school graduate", "some college" and "college and above". If the participant had a high school diploma or GED and years of education over 12, education status was categorized as "some college". Participants who had 12 years of education but without college degree were categorized as "high school". If the participant had a college degree of Bachelor or greater, his or her education was categorized as "college and above". For analysis, the education variable was categorized as: less than high school, high school, and more than high school.

Health insurance status were ascertained by four questions from HRS: "Are you currently covered by Medicare health insurance?"; "Are you currently covered by (Medicaid/STATE NAME FOR MEDICAID)?"; "We'd like to ask about all the other types of health insurance plans you might have, such as insurance through an employer or a business, coverage for retirees, or health insurance you buy for yourself, including Medigap or) other supplemental coverage."; "According to my information, you are not currently covered by any government or private health insurance plans that provide medical care. Is that correct?" The possible answers for these questions were "yes" and "no". Those who answered "yes" to the first three questions and "no" to the forth question were categorized as having health insurance, and those who answered "no" to the first three questions and "yes" to the last question were categorized as uninsured.

Household income referred to the household capital income, which sums income from self-employment, business, rental, stocks and mutual funds, bonds, CDs and treasury bills, checking and savings accounts, other assets. This variable was measured as a continuous variable in analyses.

Body Mass Index (BMI) was analyzed as a continuous variable in the models.

Self-rated health status was the participant's self-reported general health status. The code was range from 1 for "excellent" to 5 for "poor". For analysis, response categories were classified into three groups: fair/ poor, good, very good/excellent.

Current smoking status indicated whether the participant smoked the cigarettes now. The variable was coded as "yes" if the participant was a current smoker and "no" if he or she was not.

Functional limitations were coded by summing numbers of difficulties the participant had in bathing, dressing, eating, walking across the room, and using the toilet. The response score ranged from 0 to 5. For analysis, a dichotomized variable was created so that participants whose functional limitation score was "0" were categorized as none functional limitation, and whose functional limitation score was 1 to 5 were categorized as with functional limitation.

Multiple chronic conditions. The total number of chronic conditions was summed across all of those who indicated yes to a condition. Based on previous research and examination of the distribution of the data in this study, the number of chronic conditions was categorized as follows: 0-1; 2-3; 4+ conditions (Stenholm et al 2014, Hung et al 2011).

Statistical Analysis

Descriptive statistics were reported for all study variables by physical activity intensity, with means and standard deviations computed for continuous variables and frequencies and percentages calculated for categorical variables. Bivariate analyses were conducted to determine whether there were significant differences between physical activity intensity and sociodemographic (age, gender, race/ethnicity, marital status, education status, health insurance status, and household annual income) and clinical factors (BMI, self-rated health status, current smoking status, and functional limitations status). Continuous variables were compared using t-tests and categorical variables assessed with chi-square tests.

Multivariable linear regression models were used to estimate mean differences and 95% confidence intervals (CIs) for the association between light intensity physical activity level and cardiometabolic risk factors in separate models. Inclusion of variables in the adjusted models was based on prior reports of these variables as confounders of the association between physical activity and cardiometabolic risk (Loprinzi et al, 2015, Tucker-Seeley, et al, 2015, Yong et al, 2014, Pescatello, 1999). Four models were constructed for each cardiometabolic risk factor: Model 1 (MET, survey year); Model 2 (Model 1 + age, gender, race/ethnicity, marital status); Model 3 (Model 2 + education level, health insurance status, household annual income); and Model 4 (Model 3 + BMI, self-rated health, current smoking status, functional limitation). Two-sided P values <0.05 were considered statistically significant.

To assess interactions between cardiometabolic risk factors and MCC, we repeated the analyses using the final model (Model 4) and included a cross-product term for each potential interaction in the models.

Analyses were weighted to take into account the complex sampling design. All data management functions and statistical analyses were performed using SAS version 9.3, Cary, NC, USA.

Sensitivity Analysis

Several sensitivity analyses were conducted to check the following:

1) Systematic differences in the distribution of study variables between 2006 and 2008 (see Appendix A. Table A.1). The frequencies of all the study variables for 2006 and 2008 wave were compared before further analyses. In general, our study variables were statistically similar in 2006 and 2008. There were significant differences in the distribution of several variables. The average diastolic values were significantly different (2006=79.79mmHg, 2008= 79.29mmHg, p-value= 0.0214). Similarly, HbA1c values of the two waves are significantly different (2006=5.837mmol/mol, 2008= 5.907 mmol/mol, p-value=0.0001). We observed significant differences in the distribution of the data by race/ethnicity (p-value=0.0209), education level (p-value=0.004), smoking status (p-value=0.0415), numbers of MCC (p-value=0.0008) and functional limitations (p-value = 0.0009). As a result of these differences, a variable for survey year was included in the models.

2) We checked the distribution of physical activity intensity of study sample according to the previous literatures (Umstattd Meyer et al, 2015, Tucker-Seeley et al, 2012, He et al, 2005) (see Appendix A. Table A.2), and then determined the best way to categorize physical activity as Meyer et al in their study.

3) Whether the association between physical activity intensity and blood glucose would change if HbA1c was measured as categorical variable with one of two cut-points: 7.5mmol/mol and cut-point=8.0mmol/mol according to the guidelines of American Diabetes Association (ADA) (see Appendix A. Table A.3). There were no significant association between LIPA and HbA1c level for both cut-points. For both cut-points, the significant reduction of HbA1c level were only observed in participants who engaged in MIPA or VIPA.

4) Whether the association between physical activity and blood pressure would change if blood pressure was measured as a composite variable: blood pressure controlled at 140mm Hg for systolic blood pressure and 90mmHg for diastolic blood pressure (see Appendix A. Table A.4). We examined the association between different intensity of physical activity (LIPA, MIPA, and VIPA) and high systolic blood pressure only, and the association between different intensity of physical activity (LIPA, MIPA, and VIPA) and high total blood pressure (high systolic blood pressure and high diastolic blood pressure). Physical activity were not associated with high systolic blood pressure and high total blood pressure.

5) The best method to categorize MCC given the distribution of the data (see Appendix A. Table A.5). We compared 3 different ways to categorize MCC that have

been used in prior studies: a) 0-1, 2-3; 4+ conditions; b) 0 -1, 2-3, 4-5, 6+ conditions; and c) 0-1, 2, 3, 4, 5, 6+ conditions (Stenholm et al 2014, Hung et al 2014).

6) Estimates for cardiometabolic risk factors stratified by MCC (see Appendix A. Table A.6). There were no significant association between LIPA and cardiometabolic risk factors in any MCC level. Among people who have 0-1 MCC, those who engaged in moderate physical activity showed 0.094 (95% CI, -0.162, -0.025) mmol/mol decrease in HbA1c level, and those who engaged in vigorous physical activity showed 0.122 (95% CI, -0.194, -0.051) mmol/ mol decrease in HbA1c level. Among participants with 2-3 MCCs, there were no significant association detected between physical activity intensities and cardiometabolic risk factors. Among people who had 4 or more MCC, people who engaged in vigorous physical activity showed 4.047 (95% CI, 1.072, 6.937) mmHg increase in systolic blood pressure, 2.133 (95% CI, 0.471, 3.796) mmHg increase in diastolic blood pressure, and 0.167 (95% CI, -0.306, -0.026) mmol/mol decrease in HbA1c level.

CHAPTER 4

RESULTS

The distribution of physical activity levels is provided (Table 4.1). Nearly one third of the study population were living with sedentary life styles, and almost 10% of population engaged in light physical activity.

The distribution of cardiometabolic risk factors by physical activity intensity is shown (Table 4.2). The overall average systolic blood pressure for the population was 131.99 mmHg. The average systolic blood pressure for individuals categorized as sedentary was 133.40 mmHg. Average systolic blood pressure was significantly higher among those were categorized as light physical activity (141.34 mmHg, p-value= 0.0051) in comparison to sedentary individuals. Individuals who engaged in moderate to vigorous physical activity had lower systolic blood pressure in comparison to sedentary individuals (132.02 mmHg and 130.70 mmHg, p-values 0.0048, and <0.0001, respectively). The overall average diastolic blood pressure of the study population was 79.54 mmHg. There was no significantly difference in diastolic blood pressure between individuals who engaged in light physical activity and those who were in sedentary group (p-value= 0.0984). Only those who were engaged in vigorous physical activity had a significantly lower average diastolic blood pressure (79.91 mmHg), compared to sedentary individuals (79.05 mmHg; p-value= 0.0032). The overall average HbA1c of the sample population was 5.87 mmol/mol. The average HbA1c of individuals who were in the sedentary group was 6.06 mmol/mol. Individuals who engaged in light intensity physical activity had significantly lower HbA1c (5.96 mmol/mol) in comparison to the sedentary group (p-value=0.0107). Similarly, the average HbA1c were significantly lower for individuals who engaged in moderate intensity physical activity (HbA1c=5.84 mmol/mol, p-value<0.0001) and vigorous intensity physical activity (HbA1c=5.69mmol/mol, p-value<0.0001).

Table 4.3 shows the distribution of socio-demographic characteristics, life style and clinical factors by physical activity intensity. The average age of individuals who were categorized as sedentary group was 72.47. Individuals who engaged in light physical activity were significantly younger (68.01 years) than those who were in sedentary group. Similarly, the average age of individuals who engaged in moderate intensity physical activity (69.51 years) and vigorous physical activity (66.78 years) were significantly younger in comparison to those who were in sedentary group (p-value<0.0001, and p=value <0.0001, respectively). Among individuals who were categorized as sedentary group, about one-third were males (33.56%). There were no significant difference in gender composition among individuals who engaged in light intensity physical activity (p-value=0.7231). However, the percentage of males significantly increased among individuals who engaged in moderate (41.50%) and vigorous physical activity (49.16%) in comparison to individuals who were in sedentary group. Among individuals who were categorized as sedentary group, more than two thirds were Whites (71.85%), less than one fifth were African Americans (17.38%), and one tenth were Hispanics (10.77%). However, the percentage of Whites significantly increased among people individuals who engaged in light intensity physical activity in comparison to sedentary group (percentage=75.02, p-value=0.0232). Similarly, the percentage of White individuals were significantly higher among individuals who engaged in moderate (79.40%, p-value<0.0001) to vigorous physical activity (84.58%, p-value< 0.001) compared to percentage of White individuals in sedentary group. More than one third (36.44%) of individuals in sedentary group had education levels that were less than high school. However, among individuals who engaged in light intensity physical activity, the percentage of individuals whose education level was "less than high school" decreased to 25.71% (p-value<0.0001) in comparison to sedentary group. Similarly, among people who engaged in moderate to vigorous physical activity, there were significantly less people who had "less than high school" education level compared to sedentary group (percentage=23.38% and 13.68%; p-value< 0.0001 and p-value<0.0001, respectively). The percentage of married individuals was significantly higher among individuals who engaged in light physical activity (62.33%) in comparison to individuals in sedentary group (54.53%, p-value<0.0001). Similarly, the percentage of married individuals were significantly higher in moderate intensity physical activity group (65.73%, p-value=0.0001) and vigorous intensity physical activity group (74.41%, p-value< 0.0001). The average annual house capital income of individuals who were in sedentary group was $8307.41, which was significantly lower than individuals who engaged in light physical activity ($11593.74, p-value< 0.0001), moderate intensity physical activity ($13607.43, p-value<0.0001) and vigorous intensity physical activity ($26181.44, p-value<0.0001). The majority individuals who were categorized as sedentary group had health insurance (95.78%). However, the insured individuals were significantly less among those who engaged in light intensity physical activity (93.60%, p-value=0.0029) and vigorous intensity physical activity (94.63%, p-value=0.0282). Only those who engaged in moderate to vigorous physical activity had a higher percentage of non-smoker in comparison to individuals in sedentary group (85.75%).Over half (60.15%) of the individuals in the sedentary group self-rated their health status as “fair” or “poor”, but this percentage were significantly lower among individuals who engaged in light intensity physical activity (39.20%, p-value<0.0001), who engaged in moderate intensity physical activity (20.10%, p-value<0.0001), and who engaged in vigorous intensity physical activity (15.69%, p-value<0.0001). The average BMI of individuals in sedentary group was 29.23. Individuals who engaged in light intensity physical activity had insignificant lower BMI than sedentary group (28.84, p-value=27.78), but who engaged moderate (27.78) to vigorous (27.11) intensity physical activity had a significantly lower BMI than those who were in sedentary group (p-value<0.0001 and p-value<0.0001, respectively). The percentages of individuals with four or more multiple chronic conditions among those who engaged in light (21.32%), moderate (15.67%) and vigorous (9.73%) intensity physical activity were significantly lower than that in sedentary group (32.85%). On the other hand, the percentage of individuals with 0-1 multiple chronic conditions were higher in light intensity physical activity group (33.64%), moderate intensity physical activity group (36.50%), and vigorous intensity physical activity (49.53%) in comparison to that in sedentary group (20.98%). There were nearly one third (67.04%) of individuals in sedentary group had one or more functional limitations. Among those who engaged in light intensity physical activity, there were significantly less proportion of people with one or more chronic conditions

(12.98%, p-value<0.0001) in comparison to sedentary group. Similarly, those who engaged in moderate to vigorous intensity physical activity had significantly lower percentage of people one or more functional limitations compared to sedentary group (10.19% and 4.96, p-value <0.0001, and p-value< 0.0001, respectively).

Table 4.4 shows the crude and adjusted associations between systolic blood pressure and physical activity intensity. In the crude model, participants who engaged in light physical activity had a significantly lower systolic blood pressure in comparison to sedentary individuals (*B* = -2.088; 95% CI, -3.489, -0.687). After adjusting for sociodemographic characteristics, lifestyle characteristics, clinical factors, there were no significant association between light intensity physical activity and mean value of systolic blood pressure (*B*=-8.58; 95% CI, -3.379, 1.663). We observed disparities in systolic blood pressure by age, gender, race/ethnicity, education level, health insurance status, BMI, smoking status, hypertension status, and MCC levels. In the fully adjusted model, females had significantly lower systolic blood pressure compared to males (*B* = -4.254; 95% CI, -5.026, -3.482). The average systolic blood pressure were significantly higher in African Americans (*B* = 4.247 mmHg; 95% CI, 3.091, 5.403) and Hispanics (*B* = 2.081 mmHg; 95% CI, 0.701, 3.451). Individuals with education level that was higher than high school had significantly lower systolic blood pressure in comparison to those whose education level were lower than high school (*B* = -2.703; 95% CI, -3.719, -1.687). The average systolic blood pressure was significantly lower among individuals with 2-3 multiple chronic conditions (*B* = -2.874; 95% CI, -4.757, -0.990) and 4 or more multiple chronic conditions (*B* = -7.443; 95% CI, -9.589, -5.296) in comparison to those who had 0-1 multiple chronic condition. In addition, the interaction term between physical activity intensity and multiple chronic conditions showed that among individuals with 4 or more chronic conditions, the average systolic blood pressure were significantly higher among those who engaged in vigorous intensity physical activity (*B* = 4.237; 95% CI, 1.152, 7.322) in comparison to those who were categorized in sedentary group.

Table 4.5 shows the crude and adjusted association between diastolic blood pressure and light intensity physical activity intensity. After adjusting for socio-economic characteristics, life style factors and clinical factors, there were no significant associations between diastolic blood pressure and light intensity physical activity. In the crude model, participants who engaged in light (*B* = -0.103; 95% CI, -0.169, -0.037), moderate (*B* = -0.222; 95% CI, -0.266, -0.177) and vigorous (*B* = -0.374; 95% CI, -0.422, -0.327) physical activity had lower mean diastolic blood pressures compared to sedentary individuals; however after adjusting for confounders, these associations were no longer significant. For one year increase in age, diastolic blood pressure decreased by 0.107 (95% CI, -0.132, -0.081) mmHg. Females had lower average diastolic blood pressure than males (*B* = -0.451; 95% CI, -0.896, -0.005) mmHg. Blacks had significantly higher diastolic blood pressure than Whites (*B* = 1.583; 95% CI, 0.915, 2.25). The average diastolic blood pressure of individuals who were married or had education levels that were higher than high school were significantly lower than the reference groups (*B* = -0.494 and -0.593; 95% CI, -0.97, -0.017 and -1.18, -0.007, respectively). Individuals without health insurance had higher diastolic blood pressure by 0.802 (95% CI, 1.438. 3.500) mmHg comparing to individuals with health insurance. For 1 kg/m^2 increase in BMI, the diastolic blood pressure increase by 0.2444 (95% CI, 0.202, 0.285) mmHg. In addition, non-smokers had lower diastolic blood pressure comparing to people who smoke by 1.650 (95% CI, -2.286, -1.014) mmHg. In our sample, people with high blood pressure had average 4.213 (95% CI, 3.687, 4.739) mmHg higher in diastolic blood pressure than people without diagnosis of high blood pressure. However, the average diastolic blood pressure were significantly lower in diabetic individuals than non-diabetic individuals (*B* = -1.927; 95% CI, -2.509, -1.346). The average diastolic blood pressure of individuals with 2-3 multiple chronic conditions (*B* = -2.139; 95% CI, -3.227, -1.051) and 4 or more multiple chronic conditions (*B* = -5.470; 95% CI, -6.710, -4.231) in comparison to individuals who had 0-1 multiple chronic conditions. In addition, the interaction between physical activity and numbers of multiple chronic conditions showed that among individuals who had 4 or more multiple chronic conditions, the average diastolic blood pressure was significantly higher among individuals who engaged in vigorous physical activity (*B* = 2.80; 95% CI, 1.016, 4.578) in comparison to those who were classified as in sedentary group.

Table 4.6 shows the crudes and adjusted association between HbA1c level and light intensity physical activity and the 95% CI. In the crude model, each of the physical activity intensity group had a significantly lower HbA1c level in comparison to sedentary group. After adjusted for socio-economic characteristics, life style factors, and clinical factors, there were no significant association between light intensity physical activity and HbA1c. In the fully adjusted model, the average HbA1c was significantly lower among individuals who engaged in moderate (*B* = -0.097; 95% CI, -0.174, -0.020) and vigorous (*B* = -0.140; 95% CI, -0.218, -0.063) physical activity in comparison to individuals who were categorized in sedentary group. Blacks (*B* = 0.219; 95% CI, 0.171, 0.268) and Hispanics (*B* = 0.227; 95% CI, 0.169, 0.285) had significantly higher HbA1c level in comparison to Whites. The average HbA1c was significantly higher among individuals without health insurance (*B* = 0.121; 95% CI, 0.046, 0.196) compared to those with health insurance. There were 1.205 mmol/mol (95% CI, 1.162, 1.247) higher in HbA1c among diabetic individuals in comparison to non-diabetic individuals. In addition, the average HbA1c was significantly lower among individuals with 2-3 multiple chronic conditions (*B* = -0.08; 95% CI, -0.159, -0.0001) and 4 or more chronic conditions (*B* = -0.125; 95% CI, -0.215, -0.035) in comparison to those who had 0-1 multiple chronic condition. However, the interaction between physical activity and multiple chronic conditions was insignificant.

Table 4.1: Distribution of physical activity intensity

Physical Activity	N	%
Sedentary (<1.5)	3,418	28.75
Light intensity physical activity (1.5-2.9)	1,125	9.46
Moderate intensity physical activity (3.0-5.9)	4,123	34.68
Vigorous physical intensity activity (⩾6.0)	3,224	27.12

Table 4.2: Mean systolic blood pressure, diastolic blood pressure, and HbA1c by physical activity intensity, Health and Retirement Survey (2006, 2008).

	Total		Sedentary		Light			Moderate			Vigorous		
	N	Mean	N	Mean	N	Mean	P-value[a]	N	Mean	P-value[a]	N	Mean	P-value[a]
Systolic blood pressure	11564	131.99	3275	133.40	1098	141.34	**0.0051**[b]	4035	132.03	**0.0048**	3156	130.70	**<.0001**
Diastolic blood pressure	11564	79.54	3275	79.05	1098	79.75	0.0984	4035	79.59	0.0532	3156	79.91	**0.0032**
HbA1c	11645	5.87	3338	6.06	1104	5.96	**0.0107**	4035	5.84	**<.0001**	3168	5.69	**<.0001**

a p-value is from two sample t-test, each intensity of physical activity (light, moderate, and vigorous) was compared with sedentary behavior;
b bold font represents p-level less than 0.05.

Table 4.3: Socio-demographic characteristics, life style factors and clinical factors by physical activity intensity, Health and Retirement Study (2006, 2008)

Variables	Sedentary		Light			Moderate			Vigorous		
	N	%, SD	N	%, SD	**P-value[a]**	N	%, SD	**P-value[b]**	N	%, SD	**P-value[c]**
Socio-demographics											
Age (mean, SD)	72.47	10.54	68.01	9.27	**<.0001[e]**	69.51	9.51	**<.0001**	66.78	9.01	**<.0001**
Gender					0.7231			**<.0001**			**<.0001**
Male	1147	33.56	384	34.13		1711	41.50		1585	49.16	
Female	2271	66.44	741	65.87		2412	58.50		1639	50.84	
Race/ Ethnicity					**0.0232**			<.0001			<.0001
Whites	2456	71.85	846	75.02		3273	79.40		2727	84.58	
Blacks	594	17.38	188	16.71		465	11.28		274	8.50	
Hispanics	368	10.77	91	8.09		384	9.32		223	6.92	
Education					**<.0001**			**<.0001**			**<.0001**
<HS	1245	36.44	289	25.71		964	23.38		441	13.68	
HS	1109	32.46	409	36.39		1328	32.21		910	28.23	
>HS	1063	31.11	426	37.90		1831	44.41		1873	58.10	
Marital Status					**<.0001**			**<.0001**			**<.0001**
Unmarried	1554	45.47	435	38.67		1413	34.27		825	25.59	
Married	1864	54.53	690	61.33		2710	65.73		2399	74.41	
Income (Mean, SD)	8307.41	34350	11593.74	34465		13607.43	49382		26181.44	13826	
Health insurance					**0.0029**			0.7077			**0.0282**
Uninsured	144	4.22	72	6.40		181	4.39		173	5.37	
Insured	3270	95.78	1053	93.60		3938	95.61		3050	94.63	
Smoking Status					0.9349			**<.0001**			**<.0001**
Non-smoker	10147	85.75	919	81.98		3553	86.66		2884	89.79	
Current smoker	1686	14.25	202	18.02		547	13.34		328	10.21	
Self-rated health					**<.0001**			**<.0001**			**<.0001**
Fair/poor	2056	60.15	441	39.20		1241	30.10		506	15.69	
Excellent, very good or good	1362	39.85	684	60.80		2882	69.90		2718	84.31	
BMI (mean,SD)	29.23	6.98	28.94	5.93	0.2138	27.78	5.36	**<.0001**	27.11	4.72	**<.0001**

MCC					**<.0001**			**<.0001**			**<.0001**
0-1	668	20.98	363	33.64		1440	36.50		1532	49.53	
2-3	1470	46.17	486	45.04		1887	47.83		1260	40.74	
≥4	1046	32.85	230	21.32		618	15.67		301	9.73	
Functional limitations					**<.0001**			**<.0001**			**<.0001**
0	2290	67.04	979	87.02		3703	89.81		3064	95.04	
≥1	1126	32.96	146	12.98		420	10.19		160	4.96	

[a] p-value represents the comparison of variables between individuals who engaged in light intensity physical activity and those who were categorized as in sedentary group.

[b] p-value represents the comparison of variables between individuals who engaged in moderate intensity physical activity and those who were categorized as in sedentary group.

[c] p-value represents the comparison of variables between individuals who engaged in vigorous intensity physical activity and those who were categorized as in sedentary group.

[e] bold font represents a significant p-value.

Table 4.4: Crude and adjusted associations between physical activity intensity and of systolic blood pressure, Health and Retirement Study (2006, 2008)

Variable	Model 1[a]		Model 2[b]		Model 3[c]		Model 4 [d]	
	Betas	95% CI	Betas	95% CI	Betas	95% CI	Betas	95% CI
Sedentary	0.000		0.000		0.000		0.000	
Light physical activity	**-2.088**	**(-3.489,-0.687)**[e]	-0.051	(-1.421,1.320)	0.068	(-1.301,1.436)	-8.582	(-3.379,1.663)
Moderate physical activity	**-1.393**	**(-2.339,-0.448)**	0.019	(-0.910,0.949)	0.369	(-0.563,1.301)	-0.288	(-2.109,1.534)
Vigorous physical activity	**-2.723**	**(-3.725,-1.721)**	-0.144	(-1.158,0.871)	0.523	(-0.505,1.551)	-0.170	(-2.007,1.667)
Age			**0.417**	**(0.378,0.456)**	**0.413**	**(0.373,0.453)**	**0.461**	**(0.417,0.505)**
Gender								
Female			**-4.547**	**(-5.313,-3.781)**	**-4.644**	**(-5.410,-3.877)**	**-4.254**	**(-5.026,-3.482)**
Male			0.000		0.000		0.000	
Race								
White			0.000		0.000		0.000	
Black			**6.441**	**(5.315,7.567)**	**5.943**	**(4.806,7.079)**	**4.247**	**(3.091,5.403)**
Hispanic			**3.736**	**(2.447,5.024)**	**2.507**	**(1.155,3.859)**	**2.081**	**(0.701,3.451)**
Marriage								
Unmarried			0.000		0.000	0.000	0.000	
Married			**-8.715**	**(-1.689,-0.054)**	-0.642	(-1.461,0.178)	-0.519	(-1.345,0.307)
Education								
<HS					0.000		0.000	
HS					-0.637	(-1.653,0.379)	-0.850	(-1.884,0.185)
>HS					**-2.943**	**(-3.931,-1.954)**	**-2.703**	**(-3.719,-1.687)**
Health Insurance								
Uninsured					**2.813**	**(1.045,4.582)**	**3.279**	**(1.497,5.061)**
Insured					0.000		0.000	
Household Income (*10^{-6})					-3.8	(-8.3,0.7)	-2.67	(-7.1, 1.7)
BMI							**0.260**	**(0.189,0.332)**
Smoking status								
Smoker							0.000	
Non-smoker							**-3.206**	**(-4.308,-2.105)**
Hypertension								
Yes							**8.884**	**(7.974,0.795)**

No							0.000	
Diabetes								
Yes							0.599	(-0.408,1.607)
No							0.000	
MCC								
0-1							0.000	
2-3							**-2.874**	**(-4.757,-0.990)**
4+							**-7.443**	**(-9.589,-5.296)**
MCC*PA[f]								
4+MCC * VIPA							**4.237**	**(1.152,7.322)**
Functional Limitation								
None							0.000	
At least one							-0.956	(-2.086,0.175)

a: model 1: wave, physical activity
b: model 2: model 1, age, gender, race/ethnicity, marital status
c: model 3: model 2, education status, health insurance, annual household income
d: model 4: model 3, BMI, self-rated health, smoking status, hypertension, diabetes, functional limitation, multiple chronic conditions, and the interaction between physical activity and multiple chronic conditions
e: bold font represents significant 95% CI.
f: only significant groups of interaction were shown.

Table 4.5: Crude and adjusted associations between physical activity intensity and of diastolic blood pressure, Health and Retirement Study (2006, 2008)

Variable	Model 1[a]		Model 2[b]		Model 3[c]		Model 4 [d]	
	Betas	95% CI	Betas	95% CI	Betas	95% CI	Betas	95% CI
Sedentary	0.000		0.000		0.000		0.000	
LIPA	0.699	(-0.092, 1.490)	0.016	(-0.772, 0.805)	0.004	(-0.784,0.793)	-0.63	(-2.167,0.906)
MIPA	0.536	**(0.002, 1.069)**[e]	0.237	(-0.298, 0.772)	0.310	(-0.228,0.847)	-0.508	(-1.609,0.592)
VIPA	0.863	**(0.297, 1.429)**	0.193	(-0.390, 0.777)	0.312	(-0.281,0.904)	-0.853	(-1.957,0.251)
Age			**-0.161**	**(-0.183, -0.139)**	**-0.152**	**(-0.175,-0.129)**	**-0.106**	**(-0.131,-0.08)**
Gender								
Female			**-0.493**	**(-0.934, -0.053)**	**-0.531**	**(-0.972,-0.089)**	**-0.447**	**(-0.893,-0.001)**
Male			0.000		0.000		0.000	
Race/ethnicity								
White			0.000		0.000		0.000	
Black			**2.393**	**(1.745, 3.041)**	**2.281**	**(1.626,2.936)**	**1.974**	**(0.886,3.061)**
Hispanic			0.192	(-0.549, 0.933)	-0.167	(-0.946,0.612)	-0.501	(-1.841,0.839)
Marriage								
Unmarried			0.000		0.000		0.000	
Married			**-0.581**	**(-1.052, -0.111)**	**-0.49**	**(-0.962,-0.018)**	**-0.487**	**(-0.964,-0.01)**
Education								
<HS					0.000		0.000	
HS					0.102	(-0.483,0.688)	-0.261	(-0.859,0.336)
>HS					-0.42	(-0.99,0.149)	-0584	(-1.171,0.003)
Health Insurance								
Uninsured					**2.472**	**(1.453,3.491)**	**2.453**	**(1.423,3.484)**
Insured					0.000		0.000	
Annual Household Income					-0.34	**(-2.94,2.26)**	-0.41	(-2.96,2.13)
BMI							**0.244**	**(0.203,0.286)**
Smoking status								
Smoker							0.000	
Non-smoker							**-1.646**	**(-2.282,-1.01)**
Hypertension								

Yes							**4.232**	**(3.706,4.758)**
No							0.000	
Diabetes								
Yes							**-1.937**	**(-2.519,-1.355)**
No							0.000	
MCC								
0-1							0.000	
2-3							**-2.139**	**(-3.227,-1.051)**
4+							**-5.470**	**(-6.710,-4.231)**
MCC*PA[f]								
4+MCC* MIPA							**1.553**	**(0.012,3.095)**
4+MCC * VIPA							**2.801**	**(1.015,4.578)**
Functional Limitations								
None							0.000	
At least one							-0.409	(-1.061,0.244)

a: model 1: wave, physical activity
b: model 2: model 1, age, gender, race/ethnicity, marital status
c: model 3: model 2, education status, health insurance, annual household income
d: model 4: model 3, BMI, self-rated health, smoking status, hypertension, diabetes, functional limitation, multiple chronic conditions, and the interaction between physical activity and multiple chronic conditions
e: bold font represents significant 95% CI.

Table 4.6: Crude and adjusted associations between physical activity intensity and of HbA1c, Health and Retirement Study (2006, 2008)

Variable	Model 1[a]		Model 2[b]		Model 3[c]		Model 4 [d]	
	Betas	95% CI	Betas	95% CI	Betas	95% CI	Betas	95% CI
Sedentary	0.000		0.000		0.000		0.000	
LIPA	**-0.103**	**(-0.169, -0.037)**	**-0.080**	**(-0.146,-0.014)**	**-0.071**	**(-0.137,-0.006)**	-0.057	(-0.164,0.05)
MIPA	**-0.222**	**(-0.266, -0.177)**	**-0.193**	**(-0.237,-0.148)**	**-0.177**	**(-0.222,-0.133)**	**-0.097**	**(-0.174,-0.02)**
VIPA	**-0.374**	**(-0.422, -0.327)**	**-0.322**	**(-0.370,-0.273)**	**-0.293**	**(-0.342,-0.243)**	**-0.140**	**(-0.218,-0.063)**
Age			0.002	(-0.000, 0.004)	0.001	(-0.001,0.002)	**0.003**	**(0.001,0.005)**
Gender								
Female			**-0.089**	**(-0.126,-0.052)**	**-0.088**	**(-0.125,-0.051)**	-0.007	(-0.04,0.026)
Male			0.000		0.000		0.000	
Race/ethnicity								
White			0.000		0.000		0.000	
Black			**0.380**	**(0.326, 0.434)**	**0.35**	**(0.299,0.408)**	**0.219**	**(0.171,0.268)**
Hispanic			**0.442**	**(0.380, 0.504)**	**0.38**	**(0.315,0.445)**	**0.227**	**(0.169,0.285)**
Marriage								
Unmarried			0.000		0.000		0.000	
Married			-0.034	(-0.073, 0.005)	-0.026	(-0.066,0.013)	-0.026	(-0.061,0.009)
Education								
<HS					0.000		0.000	
HS					**-0.092**	**(-0.141,-0.043)**	-0.04	(-0.083,0.004)
>HS					**-0.154**	**(-0.202,-0.107)**	**-0.074**	**(-0.117,-0.031)**
Health Insurance								
Uninsured					0.035	(-0.05,0.119)	**0.121**	**(0.046,0.196)**
Insured					0.000		0.000	
Annual Household Income					**-1.71**	**(-3.86,0.045)**	0.05	(-1.82,1.92)
BMI							**0.009**	**(0.006,0.012)**
Smoking status								
Smoker							0.000	
Non-smoker							-0.005	(-0.051,0.042)

Hypertension								
Yes							-0.005	(-0.043,0.033)
No							0.000	
Diabetes								
Yes							**1.205**	**(1.162,1.247)**
No							0.000	
MCC								
0-1							0.000	
2-3							**-0.080**	**(-0.159,-0.0001)**
4+							**-0.125**	**(-0.215,-0.035)**
Functional Limitations								
None							0.000	
At least one							**-0.125**	**(-0.215,-0.035)**

a: model 1: wave, physical activity
b: model 2: model 1, age, gender, race/ethnicity, marital status
c: model 3: model 2, education status, health insurance, annual household income
d: model 4: model 3, BMI, self-rated health, smoking status, hypertension, diabetes, functional limitation, multiple chronic conditions, and the interaction between physical activity and multiple chronic conditions
e: bold font represents significant 95% CI.

CHAPTER 5

DISCUSSION

We aimed to investigate the independent association between light physical activity and cardiometabolic risk factor control among older adults. Our study indicates that physical activity intensity may have a different effect on mean levels of blood pressure and blood glucose. We did not find an independent association between light physical activity and blood pressure or blood glucose levels. However, engaging in vigorous physical activity was associated with systolic blood pressure and blood glucose levels. Also we did not find any evidence of effect modification between physical activity intensity and multiple chronic conditions.

Light Intensity Physical Activity and Cardiometabolic Risk Factors

Our results show that light intensity physical activity may not be sufficient for helping control blood pressure and HbA1c among older adults. These findings were inconsistent with the study of Loprinzi et al (Loprinzi et al, 2015), which indicated that older adults who engaged in light intensity physical activity had lower systolic blood pressure and HbA1c level in comparison to individuals who were physically inactive. However, in Loprinzi et al's study, the measurement of light physical activity was acquired by accelerometers, which were able to record all of the physical activities that the participants engaged in. In addition, the accelerometers also recorded the duration of exercise that the participants engaged in. Even after we transferred the physical activity intensity into an objective way, such information were still missing. Consequently, this inconsistency may be because that the information of light physical activity in our data were only from self-reported questionnaire, and we lacked information about duration from each participant.

Moderate and Vigorous Physical Activity Intensity and Cardiometabolic Risk Factors

Our results are consistent with previous findings that moderate and vigorous physical activity intensity is associated with reduced HbA1c level (Young et al, 2014, Loprinzi et al, 2015). In addition, our results indicated that vigorous intensity physical activity is associated more decrease in HbA1c than moderate intensity physical activity, which also underscored the findings of Loprinzi et al's study.

Our findings were inconsistent with the previous studies demonstrating that engaging in moderate to vigorous physical activity can help reduce systolic blood pressure and diastolic blood pressure. Both Loprinzi et al's and Young et al's study have found moderate to vigorous physical activity were associated with decrease in systolic blood pressure in comparison to physical inactivity. This inconsistency may largely due to the limited information of physical activity in our data.

Socioeconomic Status and Cardiometabolic Risk Factors

Our results also showed that female had significantly better control of blood pressure level comparing to males, Whites had a better control of blood pressure and glycemic control comparing to Blacks and Hispanics. People who were married, had more than high school education, or with health insurance had better control of cardiometabolic risk factors comparing to the reference groups. In addition, people with less BMI had better cardiometabolic risk factor control, and non-smokers had significant better control of metabolic risk factors comparing to smokers. These findings were consistent with previous findings that suggested the socio-economic disparities on cardiometabolic risk factors control (Tucker-Seeley et al, 2009).

Strengths and Limitations

Our study has several strengths. The HRS is a diverse nationally representative study cohort. It has a large sample size, and Blacks and Hispanics populations are oversamples, which increases the generalizability. The outcomes that were assessed objectively, for blood pressure and blood glucose, were based on objective measure using the HRS biomarker dataset. Also, our sample included individuals with multiple chronic conditions, where prior studies have typically excluded this population.

However, this study has several limitations. First, our results are cross-sectional association and cannot assess causality between physical activity intensity and cardiometabolic risk factors. The physical activity measurement in HRS is based on self-reported questionnaires, which has several limitations. For example, recall bias could exist because older adults may have greater difficulty in recalling activity; information bias may occur due to the social desirability on reporting physical activity intensities and frequencies. In addition, the lacking of duration that each time that the participants engaging in physical activity may lead to misclassification on light intensity physical activity versus physical inactivity, thus weaken the true effect of light physical activity on cardiometabolic risk factor control. Objective measurements of physical activity, such as accelerometers may provide more accurate physical activity and intensity information. However, some researches have suggested that current common exercise monitors are accurate for pace movement, such as walking and jogging, but need to be combined with self-reported questionnaire to accuracy assessment, especially when evaluating light physical activities, which contains various types of activities besides pace movement (Warms et al, 2006). Self-reported questionnaires are still widely used in epidemiological studies on physical activity, especially in those with large study population and objective measurements are hard to achieve.

There may have been measurement error in classification of light physical activity. In order to calculate physical activity intensity in METS, we weighted the data using a similar method previously used in prior studies (the frequency of light, moderate, and vigorous intensity were weighted by intensity using METS: physical inactivity: METS<1.5, light intensity physical activity: 1.5 ≤MET<3.0, moderate intensity physical activity: 3.0 < METS < 5.9, and vigorous intensity physical activity: METS ≥6.0). Although several prior studies with similar questions have used this weighting method to transform subjective physical activity data into a METS threshold, there is a possibility for nondifferential misclassification, because in our data, the information on duration of physical activity that the participant engaged each time was not available.

Additionally, there may have been inconsistency in definition of light intensity physical activity. In the present study, light physical activity was defined as vacuuming, laundry, and home repairs. However, other studies have defined light intensity physical activity including bicycle and walking (Schuna et al, 2013), which were categorized as moderate intensity physical activity in our data. There is great variability in how light intensity physical activity is defined which makes it difficult to make comparisons across studies. Another problem of self-reported based light intensity physical activity data collection is that most of the self-reported questionnaires are not sensitive enough to evaluate the light intensity physical activity, because light intensity physical activity are usually mixed in lifestyle activity such as walking and housework such as vacuuming, which added difficulty to set up the lower cut-point of light physical activity. (Warms et al, 2006).

Social desirability bias may have influenced the results of the study. It is possible that participants may have over-reported their engagement in vigorous or moderate physical activity. Prior studies have shown that social desirability bias may drive participants to over report their physical activity in intensity, duration, and frequency (Troiano RP et al, 2008).

The survey frame is another concern of self-reported questionnaires, especially among older adults. The accuracy of collected information decreases with survey frame expanded. For example, the information would be more accurate when asking participants what physical activity they have done during last week, than asking them the physical activity they have done in the past year (Ainsworth BE et al, 2012).

Conclusions

The benefits of moderate to vigorous physical activity among older adults have been well established. Our finding underscored the benefit that moderate to vigorous physical activity have on glycemic control among older adults with MCC. However, we did not find any significant associations between light intensity physical activity and cardiometabolic risk factor levels. Most of older adults given their MCCs are least likely to participate in moderate or vigorous activity levels, thus, making light physical activity an important alternative to maintain cardiovascular health. However, light intensity physical activity is not an explicit recommendation of the current physical activity guidelines for older adults. There is growing evidence suggesting that light physical activity may additionally reduce cardiovascular risk. Although we did not find an association, further studies utilizing prospective study designs and objective measures of physical activity may additionally illuminate the association between light intensity physical activity and cardiometabolic risk. Additional strategies to prevent and reduce cardiovascular risk among older adults will be important for improving and managing health.

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APPENDIX A- SENSITIVITY ANALYSIS

Table A.1 Comparisons of socio-demographic, lifestyle, and clinical variables for 2006 and 2008 Health and Retirement Study.

	2006		2008		p-value
Study variables	N	%	N	%	
METS					0.6698
Sedentary	1728	28.74	1690	28.76	
LIPA	561	9.33	564	9.60	
MIPA	2114	35.16	2009	34.18	
VIPA	1610	26.78	1614	27.46	
Outcome (Mean, SD)					
Systolic blood pressure	131.8	20.613	132.2	20.429	0.4165
Diastolic blood pressure	79.785	11.707	79.289	11.435	**0.0214**
HbA1c	5.837	0.977	5.907	0.989	**0.0001**
Age (Mean, SD)	69.431	10.040	69.529	9.767	0.5880
Gender					0.3525
Male	2466	41.01	2361	40.17	
Female	3547	58.99	3516	59.83	
Education					**0.0041**
<HS	1415	23.53	1524	25.94	
HS	1899	31.58	1857	34.61	
>HS	2699	44.89	2494	42.45	
BMI (Mean, SD)	28.019	5.790	28.228	5.880	0.0512
Race					**0.0209**
Caucasian	4758	79.13	4544	77.33	
African American	756	12.57	765	13.02	
Hispanic	499	8.30	567	9.64	
Income (Mean, SD) ($)	15334.0	97048	15270.8	59755.2	0.9660
Marriage status					0.1103
Married or partnered	3917	65.47	3746	63.74	
Unmarried	2096	34.86	2131	36.26	
Self-rated health					0.1428
Good/very good/excellent	3905	64.94	3741	63.65	
Poor, Fair	2108	35.06	2136	36.35	
Current smoking status					**0.0415**
Current smoker	814	13.60	872	14.91	
Non-smoker	5171	86.40	4976	85.09	
MCC					**0.0008**
0-1	2083	36.97	1920	33.89	
2-3	2515	44.63	2588	45.68	
≥4	1037	18.40	1158	20.44	
Functional Limitations					**0.0009**
None	5142	85.51	4894	83.30	

≥1	871	14.49	981	16.70	

Table A.2 Distribution of physical activity intensity according to different methods of categorizations.

	Tucker-Seeley		Meyer	
Physical activity intensity	N	%	N	%
Sedentary	2663	22.40	3418	28.75
LIPA	744	6.26	1125	9.46
MIPA	2236	18.81	4123	34.68
VIPA	6247	52.54	3224	27.12

Table A.3 the association between physical activity intensity and HbA1c level with cut-point 7.5 mmol/mol and 8.0 mmol/mol.

	Cut-point=7.5 mmol/mol		**Cut-point=8.0 mmol/mol**	
	Estimate	95% CI	Estimate	95% CI
LIPA	0.0025	(-.0117, .0167)	-0.0387	(-.0160,0.0083)
MIPA	**-0.1148**	**(-.0216, -.0014)**	-0.1639	**(-0.250,-.0078)**
LIPA	**-0.1130**	**(-.0227, .0001)**	-0.1533	**(-.0251, -.0056)**

Table A.4 the association between physical activity intensity and blood pressure.

	Systolic blood pressure		Total blood pressure	
	Estimate	95% CI	Estimate	95% CI
LIPA	0.009	(-.0223, .0405)	-.0025	(.0263, .0214)
MIPA	0.005	(-.0170, .0275)	.0069	(-.0010, .0239)
LIPA	0.011	(-.0142, .0361)	.0036	(-.0155, .0227)

Table A.5 Distribution of MCC by different categorization methods.

Categories of MCC	N	%
Version 1		
0-1	4003	35.42
2-3	5103	45.16
≥4	2195	19.42
Version 2		
0-1	4003	35.42
2-3	5103	45.16
4-5	1729	15.30
≥6	466	4.12
Version 3		
0-1	4003	35.42
2	2987	26.43
3	2116	18.72
4	1144	10.12
5	585	5.18
≥6	466	4.12

Table A.6 Adjusted estimates and 95% confidence intervals (CI) of the associations between physical activity intensities and outcome variables stratified by MCC.

Variable	Systolic blood pressure		Diastolic blood pressure		HbA1c	
MCC 0 or 1						
	Mean	95% CI	Mean	95% CI	Mean	95% CI
Sedentary	0.000		0.000		0.000	
Light physical activity	-1.295	(-3.688 1.099)	-0.743	(-2.155, 0.669)	-0.065	(-0.158,0.028)
Moderate physical activity	-0.797	(-2.552, 0.957)	-0.746	(-1.781, 0.289)	**-0.094**	**(-0.162, -0.025)**
Vigorous physical activity	-0.795	(-2.622, 1.030)	-0.892	(-1.969, 0.186)	**-0.122**	**(-0.194, -0.051)**
MCC 2-3						
Sedentary	0.000		0.000		0.000	
Light physical activity	0.306	(-1.748,2.359)	-0.602	(-1.787, 0.584)	0.030	(-0.056, 0.115)
Moderate physical activity	0.2717	(-1.140,1.684)	-0.142	(-0.958, 0.673)	-0.017	(-0.076, 0.041)
Vigorous physical activity	1.290	(-0.344,2.924)	-0.043	(-0.987, 0.900)	-0.045	(-0.113, 0.023)
MCC ≥ 4						
Sedentary	0.000		0.000		0.000	
Light physical activity	0.744	(-2.379, 3.867)	0.406	(-1.342, 2.154)	0.048	(-0.099, 0.195)
Moderate physical activity	1.676	(-0.595, 3.947)	1.003	(-0.269, 2.274)	-0.051	(-0.158, 0.055)
Vigorous physical activity	**4.047**	**(1.077,7.017)**	**2.133**	**(0.471, 3.796)**	**-0.167**	**(-0.306, -0.026)**