AN EXAMINATION OF PHYSICAL ACTIVITY GUIDELINES AND HEALTH-RELATED QUALITY OF LIFE AMONG OLDER ADULTS

By

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PUBLIC ABSTRACT

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Aging is associated with higher risks of chronic diseases, disability, and unhealthy lifestyle behaviors, giving rise to lower health-related quality of life (HRQoL). With rapid increase of older adult population in the U.S., poor HRQoL has become a significant public health problem. Physical activity (PA) plays an important role in improving HRQoL in the elderly. According to the PA Guidelines for Americans, adults should engage in both aerobic and muscle strengthening activities (MSA). However, previous studies of PA and HRQoL primarily focus on aerobic activity with limited research on MSA. Prior studies also provided mixed findings on sex differences. As such, the purposes of this study were to examine the association between meeting PA guidelines and HRQoL among older adults and investigate if sex moderates this relationship.

Data from 87,495 older adults aged ≥ 65 years who participated in the U.S. 2019 Behavioral Risk Factor System (BRFSS) were analyzed. The BRFSS used phone interviews and validated questionnaires to assess PA and HRQoL. Binomial logistic regression was used to assess the odds ratio of having poor HRQoL while adjusting for significant covariates.

Participants meeting both guidelines or aerobic activity guideline only were less likely to report all components of poor HRQoL (i.e., general health, mental health, physical health, activity limitation) than those who met neither guideline and those who met MSA only. Compared to respondents meeting neither guideline, those who met MSA guideline only were slightly less likely to have poor general health and poor mental health.

While meeting both aerobic activity and MSA guidelines is promising in improving HRQoL, aerobic activity contributed to the most benefits. Findings from this study can be used to inform policies, programs and interventions designed to increase HRQoL in older people.

ABSTRACT

AN EXAMINATION OF PHYSICAL ACTIVITY GUIDELINES AND HEALTH-RELATED QUALITY OF LIFE AMONG OLDER ADULTS

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Aging is associated with higher risks of comorbidity, disability, and reduced activities of daily living, which lowers health-related quality of life (HRQoL). With the rapid increase of the older adult population in the U.S., poor HRQoL in older people has become a significant public health problem. To improve HRQoL in the elderly, physical activity (PA) plays an important role. According to the PA Guidelines for Americans, adults should engage in both aerobic and muscle strengthening activities (MSA). However, previous studies of PA and HRQoL predominantly focus on aerobic activity with limited research on MSA. Prior research also provides mixed results on sex differences. Therefore, the purposes of this study were to 1) examine the associations between meeting PA guidelines and HRQoL among older adults, and 2) investigate if sex moderates the relationship between meeting PA guidelines and HRQoL.

Data from 87,495 older adults aged ≥ 65 years who participated in the U.S. 2019 Behavioral Risk Factor System (BRFSS) were analyzed. The BRFSS used phone interviews and validated questionnaires to assess aerobic activity, MSA, and HRQoL. Binomial logistic regression was used to examine the relationships between meeting PA guidelines and HRQoL while adjusting for covariates. Sex * PA was entered in logistic regression models to test the if sex was a moderator in the relationship between meeting PA guidelines and HRQoL after controlling for significant covariates.

Participants meeting both guidelines or aerobic activity guideline only had significantly lower odds of reporting all components of poor HRQoL than those who met neither guideline

(OR= 0.37-0.58) and those who met MSA only (OR= 0.34 to 0.74). No significant difference was observed in the odds of having poor HRQoL between individuals meeting both guidelines and those achieving aerobic activity guideline only. Compared to those meeting neither guideline, respondents who met MSA only had significantly lower odds of reporting poor general health (OR= 0.87, 95% CI: 0.76-0.99) and poor mental health (OR= 0.79, 95% CI: 0.66-0.93). There was no significant interaction effects of sex and PA on the odds of having poor HRQoL.

While achieving both aerobic activity and MSA guidelines is promising in improving HRQoL, aerobic activity contributed to the most benefits. Study results can be used to inform policies, programs and interventions designed to increase HRQoL in older people.

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CHAPTER I: INTRODUCTION

1.1 Background

The US older adult population is growing rapidly. In 2016, individuals aged 65 years and older made up 15% of the total U.S. population (Cacciata et al., 2019). This is expected to rise to 23.5% of the population by 2060 (Colby & Ortman, 2017). Aging is associated with increased comorbidity, disability, unhealthy lifestyle behaviors, and reduced activities of daily living, leading to lower health-related quality of life (HRQoL) (Chatterji et al., 2015). The Centers for Disease Control and Prevention (CDC) defines HRQoL as "an individual's or group's perceived physical and mental health over time" (CDC, 2000). HRQoL is an indicator of frequent hospitalization and mortality (Brown et al., 2015). HRQoL is not merely being without disease or infirmity but a person's perception of his/her overall health condition, including physical, mental, and social well-being (Karimi & Brazier, 2016). The prevalence of chronic conditions increases proportionally with age (Zhang et al., 2015). For instance, over 85% of people aged above 65 years have one or more chronic conditions such as hypertension, coronary heart disease, stroke compared to 63% of adults aged 45-64 years (Ward et al., 2014). These chronic diseases further reduce older adults' HRQoL (Ge et al., 2019). Older persons with multiple chronic diseases account for 66% of the health care budget in the US (Vincent & Velkoff, 2010). With the increase of the older population, there will be an increase of the social burden due to poor HRQoL. Therefore, it is important to identify factors that have positive effects on HRQoL in older adults.

1.2 Statement of the problem

The positive association between physical activity (PA) and HRQoL among older adults has been established (Thompson et al., 2012). Evidence from both cross-sectional and

longitudinal studies has shown PA is positively related to different domains of HRQoL (Salguero et al., 2011; Kell & Rula, 2019). The benefits of PA in older adults include reduced risk of all-cause mortality, chronic disease, and premature death (Mora & Valencia, 2018). To achieve substantial health benefits, the PA Guidelines for Americans recommend at least 150 min of moderate or 75 min of vigorous aerobic exercise (MVPA) per week or an equivalent combination of moderate- and vigorous-intensity aerobic activity (US Department of Health and Human Services [USDHHS], 2018). Additionally, they suggest that adults participate in muscle-strengthening activities (MSA) of moderate or high intensity and involve all major muscle groups on two or more days per week (USDHHS, 2018). Although a number of studies have found that individuals meeting recommended levels of PA reported better HRQoL than those not meeting recommended amounts (Xu et al., 2018; Brown et al., 2015; Brown et al., 2014; Vallance et al., 2012; Brown et al., 2003), all of them only included aerobic PA. There is limited research investigating the relationship between MSA and/or combined aerobic-strengthening PA and HRQoL. Moreover, previous research on recommended PA and HRQoL primarily examined the general population and little is known about these relationships in the elderly (Salguero et al., 2011). Currently, there are no known studies that have examined the association between meeting the aerobic activity as well as MSA guideline and HRQoL in older adults. Such evidence is important to help further establish health benefits of PA and improving HRQoL, especially in older age.

Of important consideration are sex differences in HRQoL and PA. Older men and women differ in PA levels. Examining prevalence and trends in PA among older adults across the three leading national surveys, Keadle et al. (2016) observed that more men were meeting aerobic PA and MSA guidelines than women. Consistently, a systematic review on PA in older people

showed that females were less likely to engage in regular PA than males, especially leisure-time PA when measured both subjectively and objectively (Sun et al., 2013). Sex difference also exists in the relationship between PA and various components of HRQoL. Morimoto et al. (2006) suggested that PA can have more positive effects on HRQoL for females than males. Similarly, a French study investigating the relationships of meeting MVPA with HRQoL found that most of HRQoL differences were significant when comparing inactive vs. vigorous groups, particularly in women (Vuillemin et al., 2005). On the contrary, another study noted that positive relationships between aerobic PA and the physical and mental components of HRQoL were significant in older men but not in women (Liao et al., 2020). Likewise, Xu et al. (2018) found that higher levels of aerobic PA was negatively associated with number of mental unhealthy days in men but not in women aged 60 years and above. They also noted that both medium and high PA levels were associated with less physical unhealthy days in women but only high PA level was related to the physical domains of HRQoL in men (Xu et al., 2018). Given the mixed findings regarding the sex differences on the relationships between PA and HRQoL, more research is needed to further determine the associations, especially among a nationally representative sample. Additionally, these studies predominantly stratified the data by sex instead of examining the interaction effects of sex and PA on HRQoL. Furthermore, previous studies mainly focused on aerobic PA, so it still remains unknown whether sex differences exist in the association between MSA and HRQoL in elderly adults. To address these limitations, this study will apply a nationally representative sample to examine the interaction effects of sex and PA (including both aerobic PA and MSA) on HRQoL among older adults.

1.3 Conceptual Framework

McAuley and Morris' (2007) conceptual model for lifestyle behaviors and quality of life was adapted as a framework for this study. According to this model, PA can improve individuals' HRQoL through increasing their physical function (functional performance, limitations, and disability), self-related psychological function (self-esteem, self-efficacy, affect), and cognitive function (attention, memory) (McAuley & Morris, 2007). This model has been successfully applied to diverse populations including older adults. For example, White and colleagues (2009) tested this model in community dwelling older adults and found that PA influence quality of life through self-efficacy and health-status. Moreover, Mullen and his colleagues (2012) successfully applied this model to examine the relationship between PA and HRQoL in 884 older adults with a mean age of 74.8 years from the Healthy Aging Network Study. The current study did not examine the pathways through which PA influence HRQoL. The three functions (i.e., physical function, self-related function, and cognitive function) were not investigated in this study. Instead, it focused on the relationship between PA and HRQoL after controlling for a number of important covariates.

1.4 Significance of the research

As indicated previously, findings from this study have relevance to the study population in various ways. Given the increase of the older adult population with higher risk of chronic diseases and disability, the social and economic burden of poor HRQoL are likely to grow (Prince et al., 2015). PA has been identified as a potential approach to minimize the burden on health and social care by enabling healthy aging (Hamer et al., 2014). Considering the low cost, minimal risk, and easy access associated with PA, it can be recommended to the vast majority of the elderly population (Kelley et al., 2009). However, not all types of PA have the same effects

on HRQoL in older adults (Wanderley et al. 2015). Findings from this study will offer deeper insights into the associations of meeting aerobic MVPA and MSA guidelines with HRQoL among older persons. This may be key to the development of guidelines for PA participation in elderly individuals. In addition, findings may provide practitioners with better understanding of relationships between PA and different domains of HRQoL, which will assist them in prescribing exercise to promote HRQoL in this population.

Therefore, the purposes of this study were to:

1) examine the associations between meeting PA guidelines (i.e., meeting both aerobic activity and MSA guidelines, meeting aerobic activity guideline only, meeting MSA guideline only, meeting neither) and HRQoL (i.e., general health, mental health, physical health, activity limitation) among older adults;
2) investigate if sex moderates the relationship between meeting the PA (aerobic and MSA) guidelines and HRQoL.

It is hypothesized that:

1) Adults who meet both aerobic activity and MSA guidelines will have lower odds of having poor HRQoL (i.e., general health, mental health, physical health, activity limitation) than those who meet aerobic activity guideline only or MSA guideline only or meeting neither guideline.
    a. Older adults who meet either aerobic activity or MSA guideline will have lower odds of having poor HRQoL than those meeting neither guideline.
    b. Older adults who meet aerobic activity guideline only will have lower odds of having poor HRQoL than those who meet MSA guideline only.

2) There will be significant interaction effects of sex and meeting PA guidelines on the odds of having poor HRQoL among older adults.

CHAPTER II: REVIEW OF LITERATURE

2.1 Older adults and health-related quality of life

The population of older adults is growing rapidly, accounting for 15% of the total U.S. population in 2016 (Cacciata et al., 2019). Individuals aged 65 and older are expected to outnumber children by 2035 (United States Census Bureau [USCB], 2018), which has never occurred before in U.S. history (Kell & Rula, 2019). By 2060, almost one in four Americans will be at least 65 years old (Mather & Pollard, 2015). Aging is associated with changes in body composition and functional status, leading to restricted mobility, and higher risks of frailty and mortality (Murphy et al., 2014). The elderly are likely to be faced with onset of comorbidity, disability, and changes in lifestyle behaviors, and potential loss of independence (Chatterji et al., 2015). These changes tend to lower HRQoL in older adults. As life expectancy increases, maintaining and improving HRQoL among older adults are both public and economic goals (Parekh & Myers, 2014).

HRQoL is defined as an individual's or group's perceived physical or mental health over time (CDC, 2000). It is more than living without disease or infirmity but also about how a person perceives his/her overall health condition, including physical, mental, and social well-being (Karimi & Brazier, 2016). HRQol has been linked with health status and symptoms reflecting the influence of health conditions (Zhang et al., 2015). As a fundamental concept in health research, HRQoL can be used to make decisions regarding prevention and treatment of ill health (Chai et al., 2010). Brown et al. (2015) found that HRQoL was a significant predictor of short- and long-term morbidity and mortality. The prevalence of chronic conditions increases proportionately with age (Zhang et al., 2015). For instance, over 85% of people aged above 65 years have one or more chronic conditions in contrast with 63% of adults aged 45-64 years (Ward et al., 2014).

Since HRQoL predicts mortality and hospitalizations in older adults (Benyamini, 2011; Brown et al., 2015), it is an important metric to be considered in health and well-being of older adults.

Age brings a higher risk of many chronic diseases such as heart disease, type 2 diabetes, arthritis, dementia and cancer, which are the leading causes of illness, disability, deaths, and health care cost (CDC, 2020). Health care expenditures for people with chronic and mental health account for 90% of the nation's annual health care (CDC, 2020). Vincent and Velkoff (2010) noted that older persons with multiple chronic diseases accounted for 66% of the health care budget in the US. With the increase of the older population, the social burden of poor health will grow. Given the association between poor HRQoL and future adverse health events, identifying factors that have positive effects on HRQoL in older adults could be a key component of the strategy to minimize social and health care burden and promotion of healthy aging in older adults (Michel & Sadana, 2017).

2.2 Physical activity and health-related quality of life

One way to improve HRQoL is through participating in PA. The positive association between PA and HRQoL among older adults has been well-established (Thompson et al., 2012). The benefits of PA in older adults include reduced risk of all-cause mortality, chronic disease, and premature death (Mora & Valencia, 2018). A systematic review of PA and quality of life and well-being provided strong evidence that PA interventions improved HRQoL and well-being when compared with minimal or no-treatment controls among older adults (Marquez et al., 2020). Growing evidence shows that PA promotes HRQoL by slowing down functional and psychological deterioration related to aging (Cacciata et al., 2019). The recommendation of PA in older adults should emphasize moderate-intensity aerobic activity, muscle-strengthening activity, reducing sedentary behavior and risk management (Nelson et al., 2007).

A number of studies have examined the associations between aerobic activity and HRQoL. One study on differences in HRQoL among older men meeting versus not meeting aerobic PA recommended by American College of Sports Medicine and the United States Department of Health and Human Services (USDHHS), found that meeting both guidelines was associated with higher HRQoL scores (Vallance et al., 2012). In particular, older men achieving the higher level of USDHHS's PA recommendations had higher scores on all HRQoL domains when compared to both inactive older men and those meeting the base USDHHS recommendation. Similarly, a longitudinal study in community-dwelling older adults showed that greater leisure-time PA and less sedentary behaviors were independently related to better long-term HRQoL (Balboa-Castillo et al., 2011). Examining if aerobic PA was associated with HRQoL in healthy, older adults, Acree and his colleagues (2006) determined that participants who regularly participated in PA of at least moderate intensity for more than one hour per week had higher HRQoL than those who were less physically active. A cross-sectional study investigating the relationship between the amounts of PA and HRQoL indicated that PA was positively correlated with scores for all domains of HRQoL in a sample of residents of a rural town with a mean age of 55 years (Morimoto et al., 2006). Using a nationally representative sample of older adults, a cross-sectional analysis revealed that respondents who met and exceeded aerobic PA recommended by the USDHHS had better general health, less physical and activity limitation days (Xu et al., 2018). Additionally, Brown et al. (2003) noted a lower proportion of reporting 14 or more unhealthy days among older adults who engaged in moderate or vigorous PA than those who did not. Likewise, data from 2009 Behavior Risk Factors Surveillance System survey suggested that any amount of aerobic PA in comparison to inactivity resulted in significantly lower odds of poor HRQoL among adults aged 65 years or older (Brown

et al., 2014). These studies have consistently found the positive relationships between aerobic PA and HRQoL in the elderly.

In aforementioned studies, aerobic PA was assessed by various self-reported measures. Research using device-based PA measures have also demonstrated the associations between PA and HRQoL. In 185 older institutionalized adults, PA measured for seven days by accelerometer was related to better physical functioning, physical role, vitality and less bodily pain on the Medical Outcome Study Short Form 36- Item health survey (SF-36) (Lobo et al., 2008). Moreover, a study in free-living healthy Japanese persons aged 65-85 years with PA assessed by accelerometer for one year observed poorer HRQoL among participants in the lowest quartiles of both step count and duration of activity greater than 3 METs (Yasunaga et al., 2006). Analyzing national data from 5,359 adults with a mean age of 50 years from the National Health and Nutrition Examination Survey, Kim et al. (2016) suggested that low sedentary behavior and high aerobic PA were correlated with reduced risk of poor HRQoL. By contrast, an observational study on 21 young women and 21 older women did not find significant association between objectively measured aerobic PA and HRQoL (Ciprandi et al., 2018). This finding needs to be interpreted with caution due to the small sample size. Most research evidence from device-based measured PA supported that aerobic PA benefits HRQoL among older adults.

According to PA guideline (USDHHS, 2018), both aerobic PA and muscle strengthening activity (MSA) are recommended for older adults. However, there is less research on relationships between MSA and HRQoL in elderly people. Although both cross-sectional and intervention data on the relationship between MSA and HRQoL is limited, emerging evidence suggests that older adults are able to counter several health problems by engaging in regular MSA (Hart & Buck, 2019). Such evidence will be relevant to this study. For example, MSA

benefits older adults by increasing muscle mass and strength, thus lowering the risk of premature death due to falls. An intervention study examining the effects of a 12-week systematic strength training program on changes in HRQoL among 49 older men, reported that there was an increase in all domains of HRQoL after intervention (Haraldstad et al., 2017). Further, in assessment of the effect of resistance training with elements of stretching on body composition and HRQoL in 38 women with a mean age of 62.5, it was determined that eight-week resistance training raised HRQoL in women of advanced age (Socha et al., 2016). In addition, a Japanese study investigated the effectiveness of strength training conducted twice a week for 12 weeks in 119 adults aged ≥65 years old noted that mental component of HRQoL was significantly improved in comparison to control group (Kimura et al., 2010). In examination of the effects of a 9-month resistance training intervention on HRQoL, sense of coherence, and depressive symptoms in older adults, 106 participants were randomized into four groups with different training frequency (Kekäläinen et al., 2018). Results indicated that resistance training was beneficial for environmental domain of HRQoL whereas other components were not statistically significant. Finally, a systematic review on the effect of resistance training on HRQoL in older adults supported resistance training as an effective means for improving HRQoL in the elderly (Hart & Buck, 2019). In summary, studies on muscle-strengthening interventions lasting eight weeks to nine months with relatively small samples evidenced the crucial role of MSA in promoting HRQoL in older adults.

Although health benefits of both aerobic PA and strengthening activity are well-known, it is unclear which type of exercise is more advantageous to HRQoL. Limited studies have compared effects of aerobic PA and MSA on HRQoL and provided mixed results. Investigating the effects of training on HRQoL, body composition, and function in older adults, 50

community-dwelling individuals were randomized into aerobic training, resistance training and control groups. After eight months, participants in aerobic training group had greater improvements in general health and mental health domains of HRQoL than the control group and both groups physical component of HRQoL increased compared to controls (Wanderley et al., 2015). Additionally, a significant difference in the mental health domain of HRQoL between the training groups was observed (Wanderley et al., 2015). In line with these findings, a 12-month randomized controlled trial among 179 low-active, older adults determined that physical health status component of HRQoL remained stable across the trial (Awick et al., 2015). Meanwhile, the walking group demonstrated an increase in mental health status, whereas the strengthening and flexibility group decreased significantly (Awick et al., 2015). Furthermore, evaluating the effects of 21 weeks of strength and/or endurance training on HRQoL in 204 healthy middle-aged and older adults, Sillanpää and her colleagues (2012) showed that both endurance and combined strength and endurance training were effective in improving several dimensions of HRQoL. A meta-analysis of 11 randomized controlled trails to examine the effects of PA on HRQoL in older community-dwelling individuals found no statistically significant differences between strength training and aerobic training and HRQoL outcomes, which indicated that both yield similar benefits (Kelley et al., 2009). When comparing aerobic PA and MSA on HRQoL, the results have been incongruous with some research identifying aerobic PA more beneficial to HRQoL while others did not find significant difference between the two types of PA. These studies either included a small sample, short intervention, or did not have a group that combines aerobic and strength training group, more research is needed to draw a conclusion on what type/mode of PA is more beneficial for HRQoL in older adults.

In understanding the relationship between PA and HRQoL in people with advanced age, it is important to recognize that the extent to which PA is associated with various HRQoL dimensions differs. Despite discrepant findings, more research evidence indicated that PA was more closely related to physical domain of HRQoL. Aiming to investigate whether measures of PA were associated with HRQoL and symptoms of depression older adults, cross-sectional study in a sample of 436 Spanish elderly was performed and found that PA was more related to physical component and to a lesser extent of the mental component of HRQoL (Salguero et al., 2011). Likewise, using data from 5,311 adults aged 60 years and older who participated in the National Health and Nutrition Examination Survey between 2007 and 2014, Xu et al. (2018) suggested that respondents who met and exceeded aerobic PA recommendations reported better general health and less physical unhealthy days with no difference in mentally unhealthy days by PA levels. A randomized-controlled trial comparing the training effects of aerobic and resistance training on HRQoL of older adults determined that physical component summary in both training groups increased significantly compared to the control (Wanderley et al., 2015). Moreover, a 12-week strength training intervention in elderly men revealed that physical component summary significantly increased whereas changes in mental component summary was not significant (Haraldstad et al., 2017). Brown et al. (2003) analyzed the 2001 BRFSS survey data and observed that the number of recent physically unhealthy days seemed to be more strongly associated with aerobic PA than the number of mentally unhealthy days, which was found in persons aged ≥65 years as well. In addition, using meta-analytic approach to examine the effects of PA on HRQoL in older community-dwelling adults, a trend for significant improvement in the overall physical component summary score of the SF-36 was noticed, in contrast with no significant differences among any of the other eight HRQoL outcomes (Kelley

et al., 2009). In line with these findings, reviewing evidence from cross-sectional studies, higher physical functional and vitality were more consistently correlated with higher PA levels (Bize et al., 2007). However, other studies showed conflicting findings. A three-year follow up study in 3,891 participants with a mean age of 52 years found that changes in mental component of HRQoL were more closely associated to leisure time PA than the physical component (Tessier et al., 2007). Consistently, Kimura et al. (2010) pointed out that only the mental health scale of SF-36 was significantly improved for the training group compared with controls after a strength training of 12 weeks. A majority of studies demonstrated that there were stronger associations between PA and physical domain than other domains of HRQoL, which contrasts finding that mental component was more closely related to PA.

According to current literature, both aerobic PA and strengthening training seem to be associated with better HRQoL in older adults. Given the incongruent results when comparing aerobic PA and MSA, it is unclear which type of PA has more benefits on HRQoL. Several studies have used national data to examine the relationship between meeting aerobic PA guideline and HRQoL in elderly persons. However, no known study has taken meeting MSA guideline into consideration. Little is known about the relationships between meeting aerobic activity and MSA guidelines and HRQoL in older individuals. Whether these two types of PA are related to domains of HRQoL to the same extent is unknown. Therefore, a study in older adults on population level to investigate associations between meeting the two guidelines and HRQoL is needed.

2.3 Sex difference in physical activity and health-related quality of life

In seeking to understand the relationship between PA and HRQoL in older adults, sex difference cannot be neglected. Older men and women vary in amount of PA. Examining the

percentage of older adults who meet aerobic and strength training guideline by using data from three national surveys, the study suggested that more men were meeting aerobic guidelines than women (Keadle et al., 2016). The authors also found that the proportion of those meeting the strength training guideline was significantly higher in men compared to women based on data from the Behavioral Risk Factor Surveillance System (BRFSS). Likewise, a population-based study using objectively measured PA determined that 15% older men and 10% older women participated in aerobic activity of at least 150 min/week (Jefferis et al., 2014). This is supported by the findings from Health Survey for England in adults aged over 65 years that 5% men and 0% of women adhere to the guidelines (Craig et al., 2009). Additionally, a systematic review on PA in older people showed that men were more likely to engage in regular PA, especially leisure time PA across both the subjectively and objectively measured PA studies (Sun et al., 2013). These studies found that higher percentage of older men are involved in regular PA than women. Given the benefits of PA on HRQoL, it is highly possible that sex difference exists in the relationship between PA and HRQoL.

Older males and females also differ in HRQoL. On average, women live 6-8 years longer than men (Kirchengast & Haslinger, 2008). Despite the advantage in life expectancy, women are more likely to have functional impairment in mobility and personal self-care compared to men of the same age (Orfila et al., 2006), which influences HRQoL. In a large sample of French healthy adults with a mean age of 50 years, Vuillemin et al. (2005) found that men have greater scores than women in all dimensions of HRQoL except general health. Consistently, a cohort study on non-institutionalized residents aged 65 and older found that elderly women reported lower scores on all dimensions of Nottingham Health Profile than men, which is a widely used generic tool to measure HRQoL (Orfila et al., 2006). Data from a cross-sectional study in a sample of Spanish

elderly indicated that less active men reported higher scores for the vitality and mental health domains than less active women (Salguero et al., 2011). Furthermore, analyzing sex differences in HRQoL in relation to social and biomedical factors, Kirchengast and Halinger (2008) noted that women aged ≤70 years had higher HRQoL than men of the same age. In contrast, women aged greater than 70 years had lower HRQoL than same-aged men (Kirchengast & Halinger, 2008). An earlier study in a large sample of Swedish population demonstrated the tendency for women to have lower ratings of HRQoL (Michelson et al., 2000). Previous studies seem to indicate that older women are more likely to have lower HRQoL in comparison to men of the same age group.

Sex difference exists not only in amounts of PA and HRQoL but also the association between PA and HRQoL. In examination of sex difference in PA and HRQoL, Morimoto et al. (2006) conducted a population-based cross-sectional survey study with a one-year follow-up and noted that PA of maximum intensity had positive effects on most domains of the HRQoL scale in women, but only three domains (i.e. role physical, vitality, and role emotional) in men. In line with this finding, a study from France investigating the relationships of meeting public health recommendation for aerobic activity with HRQoL in adults, determined that there were significant differences on all domains of HRQoL in women in contrast with six domains in men when comparing inactive vs. vigorous groups (Vuillemin et al., 2005). However, other studies reported conflicting results on the associations between sex and HRQoL. To determine the association between aerobic PA and HRQoL, a study on 188 community-dwelling older individuals aged 65 years or older showed that older men with higher levels of PA had better scores on both physical and mental component of HRQoL than older men with lower levels of PA (Liao et al., 2020). However, no significant association was found in women (Liao et al.,

2020). Similarly, a cross-sectional analysis using national data from 5,311 adults aged 60 years and older who took part in the National Health and Nutrition Examination Survey found that PA was inversely related to number of mental unhealthy days in men but not in women (Xu et al., 2018). Meanwhile, it was also found that PA of both medium and high levels were associated with physical unhealthy days in women but only high PA level was linked to physical component of HRQoL in men (Xu et al., 2018). Though sex difference in relationships between PA and HRQoL has been noted, prior research has presented mixed findings. These studies predominantly examined aerobic PA. It remains unknown whether older men and women differ in the association between achieving aerobic activity or/and MSA guidelines.

2.4 Measurement of health-related quality of life

With the rapid increase in the number of older adults, evaluating HRQoL among the elderly has become very important. HRQoL research originated from two fundamental approaches: health status and health value/preference/utility assessment (Khanna & Tsevat, 2007). Health status measures are designed to assess an individual's functional ability in one or more domains, whereas health utility measures attempt to estimate a person's value or desirability of a state of health (Der-Martirosian et al., 2010). There are various measures of health status and health utility. The most widely used HRQoL measures are Short-Form 36 Health Survey (SF-36), Short-From 12 Health Survey (SF-12), and HRQoL-4.

The SF-36 is a measure with 36 items that has been widely used to assess self-reported HRQoL (Ware & Gandek, 1998) and to monitor trends and changes in population health status over the past few decade (Kroenke et al., 2008). The SF-36 comprises eight physical and mental health domains: physical functioning, role physical, bodily pain, general health, vitality, social functioning, role emotional, and mental health. These eight domains can be further aggregated

into two components: physical component summary (PCS) and mental component summary (MSC). PCS includes physical functioning, role physical, bodily pain, and general health whereas MSC includes vitality, social functioning, role emotional, and mental health. Domains scores range from 0 to 100, with higher scores indicating better HRQoL. In the general US population, the physical and mental component summary each has a mean score of 50 and standard deviation of 10, whereas mean scores for the eight domains range from 61 to 84 and standard deviations range from 18 to 34 (Ware et al., 1994). The SF-36 has been extensively used in observational studies and clinical trials in diverse populations (Ferrucci et al., 2004; Brazier et al., 1992).

As a shorter version of the SF-36, the SF-12 is another valid and reliable HRQoL measure (Ware et al., 1996). It consists of twelve items included in the SF-36. The SF-12 also covers the same eight domains as the SF-36. Compared to other longer version measures of HRQoL, the SF-12 is preferable because it can be completed in less than 2 mins, which is about 10 mins faster than SF-36 (Pickard et al., 1999). A number of studies have shown high correlations between SF-36 and SF-12 scores in older adults (Ware et al., 1996; Côté et al., 2004; Müller-Nordhorn et al., 2004). The SF-12 was found to reproduce more than 90% of the variance in PSC and MSC of the SF-36 measure and has also been used widely to measure HRQoL (Ware et al., 1996). It provides a summary assessment of both physical and mental health status. The SF-12 scores can range from 0 to 100, with higher scores indicating better health status. The mean (SD) normative scores for physical and mental health status are 44.29 (10.87) and 52.26 (10.07) respectively (Ware, 2001).

To meet the need for a brief and valid measure of HRQoL in the general population, the CDC developed a 4-item set of HRQoL (HRQoL-4; Hennessy et al., 1994). The HRQoL-4 was

derived from the original version of SF-36 (Ware et al., 1992; Moriarty et al., 2003). The four questions assess general health, physical health, mental health, and activity limitation. Each of the four HRQoL measures has its own indicator and there is no composite HRQoL score (Moriarty et al., 2003). The HRQoL-4 has undergone extensive reliability and validity testing and shown adequate psychometric properties (Hays et al., 2009; Jiang & Hesser, 2009; Horner-Johnson et al., 2009; Mielenz et al., 2006). It has been used in numerous epidemiological studies (Moriarty et al., 2003; Ôunpuu et al., 2001; Ford & Li, 2008).

In summary, the most widely used HRQoL measures are SF-36, SF-12, and HRQoL-4. Both SF-12 and HRQoL-4 scale are based on SF-36. The SF-12 is advantageous in some situations because it takes less time for participants to complete. For the SF-36 and SF-12, scores are calculated which ranges from 0 to 100 with higher scores indicating better HRQoL. By contrast, there is no composite score for HRQoL-4. For the BRFSS, the CDC uses HRQoL-4 and data on HRQoL in the current study was collected using this instrument.

2.5 Measurement of physical activity

It is well-known that PA benefits HRQoL in older adults. To evaluate levels of PA, it is important to understand measurement of PA among older people. There are some challenges in measurement of PA in older adults (Kowalski et al., 2012). For example, older persons may have difficulties in understanding instructions on self-report measures and recalling PA behaviors over longer period of time due to changes in cognitive abilities and memory. Since the metabolic costs of activities change with aging and disability, standard tables and equations developed on younger population that are used for calculating energy expenditure of activities may not be appropriate for older adults (Rikli, 2000; Harada et al., 2001; Murphy, 2009). In previous studies,

self-reported and objective measures were widely used to assess levels of PA among older individuals.

Self-reported PA measures include established protocols (CDC,2001), Global Physical Activity Questionnaire (GPAQ; Armstrong & Bull, 2006), Godin Leisure-Time Exercise Questionnaire (GLTEQ; Godin & Shephard, 1985), Yale Physical Activity Survey (YPAS; Dipietro et al., 1993), International Physical Activity Questionnaire (IPAQ; Bauman & Sallis, 2008), and Minnesota Leisure Time Physical Activity Questionnaire (MILTPAQ; Taylor et al., 1978). The CDC uses six questions to assess participation in moderate to vigorous, nonoccupational aerobic PA and one questions to assess MSA in a week. Yore et al. (2007) demonstrated acceptable validity and reliability of these survey items. The GPAQ is a recall of PA behaviors in specific domains, such as work, travel, recreational activity, and inactivity (Armstrong & Bull, 2006). It was designed to evaluate prevalence of PA over time, to compare regional and global differences in PA levels, and to inform decisions about PA policy (Armstrong & Bull, 2006). Herrmann et al. (2013) provided evidence of low-to-moderate validity and generally acceptable reliability for the GPAQ.

The GLTEQ contains three items assessing the average frequency and duration of mild, moderate, and strenuous PA an individual performed during leisure time over a typical week during the past month (Godin & Shephard, 1985). Previous studies have shown the GLTEQ to be a reliable and valid measure of self-reported PA (Godin, Jobin, & Bouillon, 1986; Jacobs, Ainsworth, Hartman & Leon, 1993). The YPAS, developed by Dipietro et al. (1993), is an interview-administered questionnaire. It was developed to estimate PA in older adults. The YPAS includes types and intensities of recreational, household, and exercise activities that are part of many older adults' lifestyle, which are often excluded by other types of PA questionnaire

(Kruskall et al., 2004). The YPAS has demonstrated adequate repeatability (DiPietro et al., 1993) and acceptable validity (Harada et al., 2001). The IPAQ is a standardized self-reported questionnaire that provides an estimate of PA and sedentary behavior for adults aged 15 to 69 years with diverse socio-economic settings (Craig et al., 2003). It has two versions: the 31-item long form (IPAQ-LF) and the 9-item short from (IPAQ-SF). Several studies have established validity and reliability of the IPAQ (Rütten et al., 2003; Qu et al., 2004; Kurtze et al., 2008). The IPAQ has become the most widely used PA questionnaire (van Poppel et al., 2010). The MILTPAQ comprises a list of 63 recreational, sport, yard, and household activities (Taylor et al., 1978). It showed high reliability (Folsom et al., 1986) and good validity (Richardson et al., 1994).

Self-reported PA measurements are practical, easy to administer to large groups, and cost-efficient (Kowalski et al., 2012). They place relatively low burden on participants and researchers and have little interference with individuals' usual activities (Kowalski et al., 2012). However, they are subject to either under or over-estimation due to recall bias, social desirability and misinterpretation (Wilcox & Ainsworth, 2009).

An alternative to self-reported measures is objective measures, such as accelerometers, pedometers or combined monitors. The ActiGraph accelerometer was used in the National Health and Nutrition Examination Survey to measure PA (Kim et al., 2017; Loprinzi et al., 2015). Ciprandi et al. (2018) used the Actiheart to provide an accurate assessment of PA, which is able to combine heart rate and movement monitor signals. Objective measures are generally more accurate since they are not prone to response and recall bias (Prince et al., 2008; Forsén et al., 2010). However, objective measures are more expensive, intrusive, time-consuming, and place a higher level of burden on both participants and researchers than self-reported measures

(Prince et al., 2008). Moreover, participants may change their behavior since they know it is being measured (Wilcox et al., 2009). Additionally, some objective measures (e.g., accelerometers, pedometers) provide limited information about type of activity (Murphy, 2009) and is not appropriate to measure certain types of PA (e.g., swimming, resistance exercise, cycling; Wilcox et al., 2009).

PA in older adults is assessed by self-reported and objective measures. Although self-reported measures are useful to evaluate PA in large populations due to their practicality, low cost and low burden, they are prone to recall and response bias. By contrast, objective measures provide more precise assessment but are often more cost and time consuming and intrusive, which is difficult to apply in large epidemiologic settings. Regardless of measurement of PA, most studies confirmed the positive association between PA and HRQoL among older adults. Established protocols (CDC, 2001) are used to measure PA in the BRFSS, which is where data for the current study is from.

2.6 Sociodemographic, biological, and behavioral factors and HRQoL

A cross-sectional study with 257 healthy community-dwelling older people found participants aged 65-84 years had a significantly higher level of HRQoL than those aged 85 years and older in both physical and mental domains (Etxeberria et al., 2019). This is supported by earlier studies suggesting that age was associated with a lower level of HRQoL (Lim & Fisher, 1999; Al-Windi et al., 1999). An examination of race difference in HRQoL among 5,986 elderly persons aged 65 years and over, Skarupski et al. (2007) showed that blacks had a significantly higher risk of having poor overall HRQoL than whites, which was consistent with prior research (Collins et al., 2002). In addition, many studies found that Hispanics had better

health than non-Hispanic whites as they had relatively lower mortality rates (Markides & Coreil, 1986; Markides & Eschbach, 2005; Crimmins et al., 2005).

Education has been identified as another important factor associated with HRQoL. Evidence from many studies has demonstrated that more formal education has preventive effects as it lowers health risk, improves cognition, and prolongs life expectancy (Mäki et al., 2014; Majer et al., 2011; Lutz & Samir, 2011). Furthermore, Bielderman et al. (2015) noted that socioeconomic status (SES) had significant indirect effects on quality of life in older adults. As another indicator of SES, income has been found to influence HRQoL as well. Assessing the independent effect of income on HRQOl among older adults in Canada and the U.S, data from the Joint Canada/United States Survey of Health 2002-2003 suggested a clear and significant positive relationship between household income and HRQoL in older adults in the U.S, whereas the relationship was not evident in Canada (Huguet et al., 2008).

Marital status is also an important factor in HRQoL of older individuals. Research on health and mortality by marital status has consistently demonstrated that unmarried persons generally reported poorer health and had a higher mortality rate than their married counterparts (Johnson et al., 2000; Rohrer et al., 2008; Waite, 1995), and this is particularly the case for men (Valkonen et al., 2004). To estimate the overall risk of mortality for different categories of marital status in the elderly, a meta-analysis of cohort studies was conducted and showed that marriage had a significant protective effect on health across different countries (Manzoli et al., 2007). For older adults, a common life event is retirement. As life expectancy increases, many older people choose to continue to participate in workforce in some way after retirement (Tang et al., 2013). A comparison study among Korea, Germany, and Switzerland indicated that participants working continually after retirement had greater life satisfaction than those who

were fully retired or unemployed in both Germany and Switzerland (Cho & Lee, 2014). Additionally, research evidence has consistently shown that unemployed persons reported significantly lower HRQoL than employed people in the general population (Lee et al., 2015).

Considering the increasing prevalence of obesity in older adults and its association with many chronic diseases (Decaria et al., 2012), BMI is a crucial factor in determining HRQoL. To examine relationships of BMI with HRQoL in older adults, a study of 7,080 participants aged 65 years and older established that obesity was strongly associated with lower HRQoL for both men and women in the health perception domain and physical domains (Yan et al., 2004). Further, they also noted that the relationship between BMI and HRQoL was not linear with both underweight and obese older persons having poor HRQoL than those with normal weight (Yan et al., 2004). As an individual ages, the risk of having various comorbidities is higher (Zhang et al., 2015). In understanding the relationships among multiple chronic conditions, limitations in activities of daily living, and HRQoL in older adults, a longitudinal study was conducted in 27,334 participants aged 65 years and above by using data from the 2004-2006 Medicare Health Outcomes Survey (Barile et al., 2013). It was found that both baseline and new multiple chronic conditions led to worse health in terms of both activities of daily living and HRQoL (Barile et al., 2013).

Health behaviors are key determinants in maintaining good health and promoting successful aging (Watt et al., 2014). Smoking and heavy alcohol consumption have been associated with higher risk of disability and death in older people (Chakravarty et al., 2012). Several studies have shown that excessive alcohol consumption is harmful to health (Giesbrecht et al., 2011; Ronksley et al., 2011). Nevertheless, data from a nationally representative sample of 5,404 older adults from the longitudinal National Population Health Survey demonstrated that

alcohol consumption was generally not associated with greater decline in HRQoL regardless of quantity and frequency (Kaplan et al., 2012). Assessing the relationship between smoking status and HRQoL in a large sample of the U.S. general population, Mody and Smith (2005) found that smoking status was independently and significantly associated with self-related HRQoL. They also observed that current smokers were more likely to have poorer general health compared to nonsmoker and ex-smokers (Mody & Smith, 2005). Additionally, Gasperini et al. (2017) investigated the relationship between HRQoL and age when individuals quit smoking in older Italian adults and concluded that earlier smoking cessation could have a positive effect on HRQoL.

2.7 Summary

Older adults account for a large percentage of the total population in the U.S. and this number is increasing fast. Aging is associated with reduced HRQoL, leading to higher social and economic burden. The benefits of PA have been widely known and has been identified as a low-cost, non-pharmaceutical approach to maintain and improve HRQoL in older adults. According to the PA Guidelines for Americans, both aerobic activity and MSA are recommend for adults (USDHHS, 2018). The current body of literature has showed positive relationships between these each type of PA and HRQoL in elderly individuals, however, gaps remain that may be key to health promotion in the elderly populations. Compared to aerobic activity, fewer studies have examined association between MSA and HRQoL as well as how meeting aerobic activity and/or MSA guideline are related to HRQoL. Additionally, many studies have found sex difference on PA and HRQoL, yet they presented inconsistent findings with a focus on aerobic PA. Little is known about whether aerobic activity and MSA have different associations with HRQoL in older men and women. Research addressing some or all of these limitations would be very valuable in

strengthening the argument that engaging in regular PA plays an important role in older adults' HRQoL. This has implication on PA guidelines for older adults.

CHAPTER III: METHODS

3.1 Overview research design and data source

This study is a secondary analysis of data from the 2019 BRFSS (CDC, 2020). The CDC operates this data system and makes the data open source. The BRFSS is the largest continuously conducted health system in the world, which collects data via landline and mobile/cell phone surveys from non-institutionalized U.S. residents aged 18 years and older in all 50 U.S. states as well as the District of Columbia and three U.S. territories (CDC, 2018). Established in 1984, the BRFSS completes more than 400,000 adult interviews each year regarding their health-related risk behaviors, chronic health conditions, and use of preventive health practices (CDC, 2014). The median response rate for all states and territories was 49.4% in 2019 (CDC, 2020).

The CDC collaborates with the state health departments by providing technical and methodological assistance to administer BRFSS surveys (CDC, 2018). The state health departments use in-house interviewers or contract with telephone call centers or universities to conduct BRFSS surveys continuously through the year. The 2019 BRFSS survey includes the core component, optional modules, and state-added questions (CDC, 2019). The survey is conducted by using Random Digit Dialing (RDD) techniques on both landlines and cell phones (CDC, 2019). The target population for cellular telephone samples in 2019 consisted of adults (aged 18 years and older) living in a private residence or college housing who have a working cellular telephone (CDC, 2019). When conducting the landline telephone survey, interviewers collected data from a randomly selected adult in a household. For cellular telephone survey, data were obtained from adults who answered the cellular telephones residing in a private residence or college housing (CDC, 2019).

In 2019, Computer-Assisted Telephone Interview (CATI) systems were used in 53 states or territories for data collection (CDC, 2019). CDC supported CATI programming by using the Ci3 WinCATI software package, which included programming the core and module questions for data collectors, providing questionnaire scripting of state-added questions, and contracting with a Ci3 consultant to assist states (CDC, 2019). State health personnel or contractors conduct interviews following BRFSS guidelines. The core portion of 2019 BRFSS questionnaire lasted an average of 17 minutes. Depending on the number of questions used for optional and state-added questions, an additional 5 to 10 minutes were needed (CDC, 2019).

The 2019 BRFSS comprised of a variety of items, including (but not limited to) demographic variables, health conditions, health behaviors, and health related outcomes. This study focuses on PA and HRQoL. From the 418,268 adults who originally participated in the 2019 BRFSS, participants were included if they were aged ≥65 years old (n = 154,701). Participants were excluded if they had any missing data on PA (n = 21,313), HRQoL (n = 7,186), or other covariates (n = 38,504). The final sample in this study was 87,495 (participants flow diagram shown in Figure. 1).

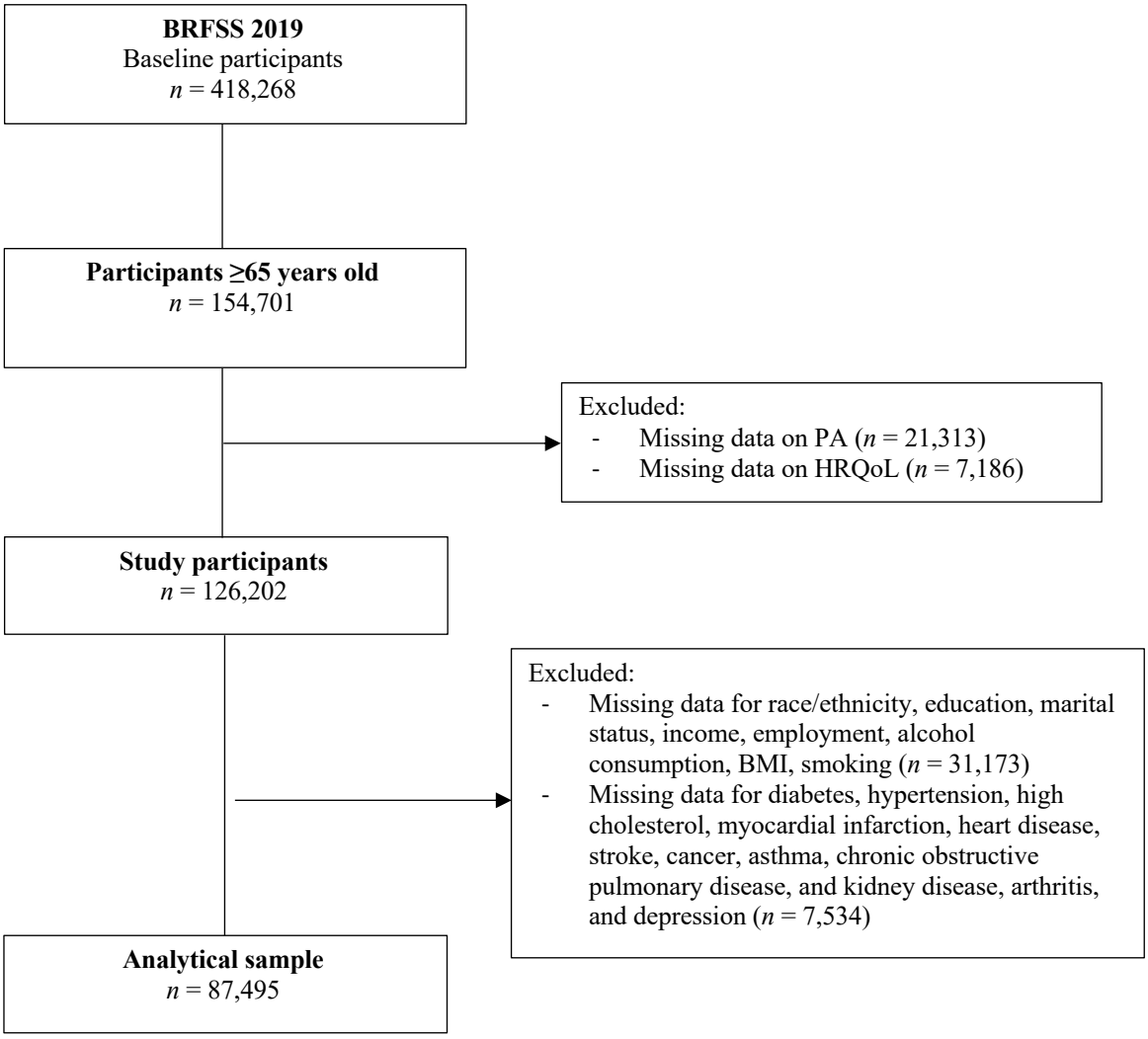

Figure 1. *Behavioral Risk Factor Surveillance System 2019 participants flow diagram*

3.2 Physical activity assessments

Self-reported aerobic activity and MSA were estimated by using established protocols (CDC, 2001). Aerobic PA was assessed by asking participants "*During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?*". If the respondent indicated 'yes', they were then asked "*What type of physical activity or exercise did you spend the most time doing during the past month?*" and further inquired; "*How many times per week or per month did you take part in this activity during the past month?*" and "*When you took part in this activity, for*

how many minutes or hours did you usually keep at it?" (CDC, 2019) (Table 3.1). Participants then asked if they had a second activity that they engaged in during the past month. If they answered 'yes', then detained information on type, frequency, and duration was recorded by asking same follow-up question as the first activity. An aerobic activity had to be performed ≥10 minutes per episode to count toward meeting the aerobic guideline (Yore et al., 2007). To estimate the intensity of aerobic activity, the criterion MET value for vigorous-intensity activity (VPA) is 60% of estimated maximal oxygen uptake based on sex and age (CDC, 2001). Moderate-intensity activities (MPA) is defined as ≥3 METs based on evidence-based recommendations (CDC, 2001). These survey items have been demonstrated to have acceptable criteria-related validity (Cohen's k = 0.17-0.22) (using accelerometer as the criteria) and test-retest reliability (Cohen's k = 0.67-0.84) (Yore et al., 2007).

Consistent with the 2018 PA guidelines for Americans, meeting the aerobic PA guideline is defined as at least 150 min/week moderate-intensity, or 75 minutes/week of vigorous-intensity aerobic PA, or an equivalent combination of both (USDHHS, 2018). Since the amount of energy consumed in VPA is approximately double that of MPA (Gebel et al., 2015), time spent in aerobic vigorous-intensity PA was doubled. Each respondent's weekly total minutes of MVPA was determined by multiplying weekly minutes of VPA by two and adding the weekly MPA minutes (CDC, 2001). For example, if a participant reported 90 mins of MPA and 30 mins of VPA, the volume of weekly MVPA is 90 + 30*2 = 150 min/week. A participant was determined to meet the aerobic guideline if he/she participated in at least 150 minutes of moderate PA per week.

MSA was assessed by asking "*During the past month, how many times per week or per month did you do physical activities or exercises to strengthen your muscles?*" Respondents were

reminded, “Do not count aerobic activities like walking, running, or bicycling. Count activities using your own body weight like yoga, sit-ups or push-ups and those using weight machines, free weights, or elastic bands” (CDC, 2019) (Table 3.1).This item has acceptable test-retest reliability (Cohen’s k = 0.85-0.92) and validity (Cohen’s k =0.40-0.52) (correlated with PA log) (Yore et al., 2007). The 2018 PA guidelines for Americans defined meeting the MSA guideline as engaging in muscle-strengthening exercise of moderate or high intensity that involve all major muscle groups on 2 or more days a week (USDHHS, 2018). Respondents reported their MSA frequency for sessions/week or sessions/month. For those reporting their MSA frequency by sessions/month, it was divided by four to obtain weekly frequency. An older adult was classified as meeting MSA if he/she participated in MSA for at least two sessions per week.

Table 3. 1

PA Survey Questions

Variable	**Question from the 2019 BRFSS**	**Potential Response**	**Interviewer Notes**
Aerobic PA	During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?	1= Yes 2= No	If respondent does not have a job or is retired, they may count the PA or exercise they spend the most time doing in a regular month.
	What type of physical activity or exercise did you spend the most time doing during the past month?	__ __ Specify from PA coding list	If the respondent’s activity is not included in the PA coding list, choose the option listed as “other”.
	How many times per week or per month did you take part in this activity during the past month?	1__ Times per week 2__ Times per month	
	When you took part in this activity, for how many minutes or hours did you usually keep at it?	____: ___ ___ Hours and minutes	
	What other type of physical activity gave you the next most exercise during the past month?	__ __ Specify from PA coding list	If the respondent’s activity is not included in the PA coding list, choose the option listed as “other”.
	How many times per week or per month did you take part in this activity during the past month?	1__ Times per week 2__ Times per month	
	And when you took part in this activity, for how many minutes or hours did you usually keep at it?	____: ___ ___ Hours and minutes	

Table 3. 1 (Cont'd)

MSA	During the past month, how many times per week or per month did you do physical activities or exercise to strengthen your muscles?	1__ Times per week 2__ Times per month	Do not count aerobic activities like walking, running, or bicycling. Count activities using your own body weight like yoga, sit-ups or push-ups and those using weight machines, free weights, or elastic bands.

3.3 Physical activity classification categories

Following the PA guidelines for Americans (USDHHS, 2018), each respondent was categorized into one of the four groups: 1) meeting neither guideline (aerobic MVPA = 0-149 min/week & MSA< 2 sessions/week); 2) meeting MSA guideline only (MSA ≥2 sessions/week & aerobic MVPA = 0-149 min/week); 3) meeting aerobic activity guideline only (aerobic MVPA ≥150 min/week & MSA< 2 sessions/week); 4) meeting both aerobic activity and MSA guidelines (aerobic MVPA ≥150 min/week & MSA ≥2 sessions/week) (Table 3.2).

Table 3. 2

Categories of meeting PA guidelines

PA Guidelines	**Aerobic activity**	**MSA**
Meeting neither	0-149 min/week	< 2 sessions/week
Meeting MSA only	0-149 min/week	≥2 sessions/week
Meeting aerobic activity only	≥150 min/week	MSA< 2 sessions/week
Meeting both	≥150 min/week	≥2 sessions/week

3.4 Health-related quality of life

Questions assessing HRQoL are from two mandatory sections of BRFSS: Health Status (one question) and Healthy Days (three questions). These four questions comprise the CDC's HRQoL-4 scale, which covers the individual general health status, physical health, mental health and activity limitations (CDC, 2018) (Figure 2). The HRQoL-4 scale has been included in the BRFSS questionnaire since 1993 (CDC, 2018). It has been found to have good validity with

respect to the Medical Outcomes Study Short-Form 36 (Newschaffer,1998) and moderate to excellent reliability (Cohen's *k*/interclass correlation coefficient = 0.57-0.75) (Andresen et al., 2003).

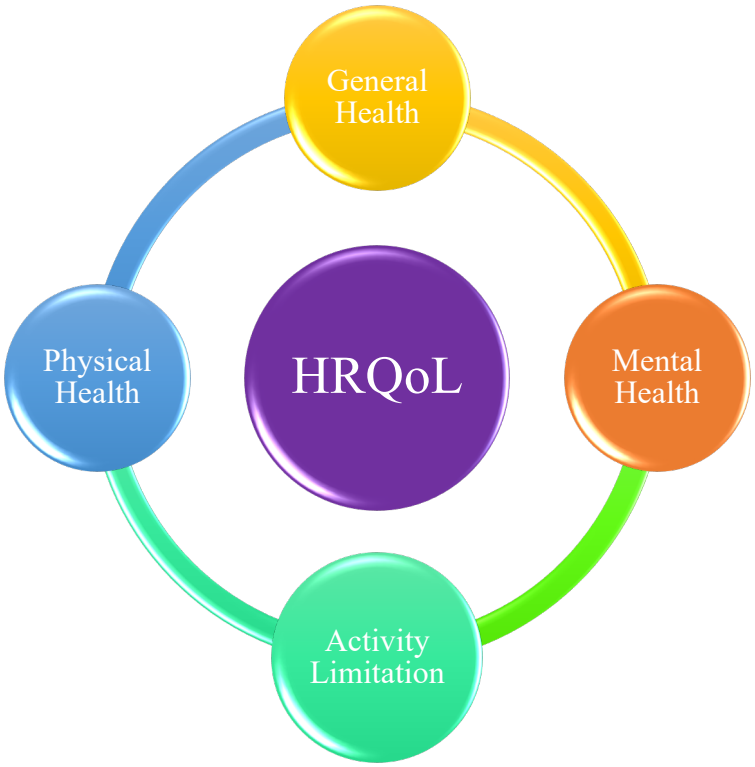

Figure 2. *Different factors of HRQoL*

The question on Health Status asked respondents to rate their general health "Would you say that in general your health is: ..." to which participants indicated "Excellent," "Very good," "Good," "Fair," or "Poor" (CDC, 2019). Response to the Health Status was dichotomized into good ('excellent', 'very good', 'good') and poor ('fair', 'poor') (Shockey et al., 2017; Pate et al., 2019). This measure has been shown to have good validity in estimating population health and good alignment with health assessment by physician, as well as capacity to predict morbidity and mortality (Bombak, 2013).

The three HRQoL items in the "Healthy Days" section are used to assess mental health, physical health, and activity limitation. "Healthy Days" measures are considered as an

acknowledged standard "health report cards" for health surveillance on a population level by national and international groups and have been validated in several population groups in different nations including the U.S., Sweden, Canada, and Italy (CDC, 2018). The Healthy Days section comprised three questions: (1) "Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good?" (physical unhealthy days); (2) "Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?" (mentally unhealthy days); and (3) "During the past 30 days, for about how many days did poor physical or mental health keep you from doing your usual activities, such as self-care, work, or recreation?" (activity limitation days) (CDC, 2019) Answers for the three questions range from 0 to 30 days. Besides "no activity limitation" responses, if the respondent indicated "no" physically and mentally unhealthy days, and response to activity limitation days question was missing, then the number of days of activity limitation was considered as "none" (CDC, 2019).

Based on CDC HRQoL program guidelines, response to "Healthy Days" was dichotomized as <14 unhealthy days (infrequent unhealthy days) and ≥14 unhealthy days (frequent unhealthy days) (CDC, 2018). The 14 days cut-off is in line with prior research utilizing these questions (Pate et al., 2019; Potter & Patterson, 2019; Brown et al., 2014). Fourteen or more unhealthy days for mental health are considered as markers of clinical depression and anxiety disorders (Brown et al., 2015; Brown et al., 2014). Fourteen or more unhealthy days for physical health are associated with more physical distress and activity limitation (Dwyer-Lindgren et al., 2017; White et al., 2019). Furthermore, given the distribution of the data (a considerable number of participants reported zero unhealthy days), dichotomizing

unhealthy days (poor physical, mental or activity limitation vs. good physical, mental or activity limitation) allowed conducting statistical analysis without violating assumptions.

Table 3. 3

HRQoL-4 survey questions

Variable	**Question from the 2019 BRFSS**	**Potential Response**	**Interviewer Notes**
General Health	Would you say that in general your health is ____	1= Excellent 2= Very Good 3= Good 4= Fair 5= Poor	
Physical Health	Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good?	__ __ Number of days (01-30) 0= None	
Mental Health	Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?	__ __ Number of days (01-30) 0= None	
Activity Limitation	During the past 30 days, for about how many days did poor physical or mental health keep you from doing your usual activities, such as self-care, work, or recreation?	__ __ Number of days (01-30) 0= None	Do not ask this question and skip to next section if both physical health and mental health are 0.

3.5 Covariates

Sex, age, race/ethnicity, education, marital status, income, employment, alcohol consumption, body mass index [BMI], smoking and comorbidities were included in models since previous research has shown that they are associated with HRQoL among older adults (Xu et al., 2018; Etxeberria et al., 2019; Skarupski et al., 2007; Huguet et al., 2008; Bielderman et al., 2015; Kim et al., 2018; Yan et al., 2004; Gasperini et al., 2017; Kaplan et al., 2012).

Table 3. 4

Variables as covariates

Confounding Variable Name	**Variable Description**
Sex	Are you male or female? 1= Male 2= Female
Age	What is your age? 1 = 65-74 2 =>75
Race/ethnicity	Which one or more of the following would you say your race? 1= White non-Hispanic 2= Black non-Hispanic 3= Other race non-Hispanic 4= Multiracial non-Hispanic 5= Hispanic
Education	What is the highest grade or year of school you completed? 1= Did not graduate high school 2= Graduated high school 3= Attended college/technical 4= Graduated college
Marital status	Are you…? 1= Married 2= Divorced 3= Widowed 4= Separated 5= Never married 6= A member of an unmarried couple
Income	How much is your annual income from all sources? 1= Less than $15,000 2= $15,000- $25,000 3= $25,000- $35,000 4= $35,000- $50,000 5= $50,000 or more
Employment	Are you currently...? 1= Student 2= Employed 3= Unemployed 4= Homemaker 5= Retired 6= Unable to work
Alcohol consumption	Drink any alcoholic beverages in past 30 days? 1= Yes 2= No
BMI	Calculated from height and weight 1= Underweight (< 18.5) 2= Acceptable weight (18.5-25) 3= Overweight (25-30) 4= Obese (≥30)
Smoking	Are you a current smoker? 1= No 2= Yes
	Has a doctor, nurse, or other health professional ever told you had any of the following? 1. Diabetes 1= Yes 2= No 2. High blood pressure

Table 3. 4 (cont'd)

Comorbidities	1= Yes 2= No 3. Blood cholesterol is high 1= Yes 2= No 4. Myocardial infarction/coronary heart disease 1= Yes 2= No 5. Stroke 1= Yes 2= No 6. Asthma 1= Yes 2= No 7. Skin cancer 1= Yes 2= No 8. Any other types of cancer 1= Yes 2= No 9. Chronic obstructive pulmonary disease 1= Yes 2= No 10. Arthritis 1= Yes 2= No 11. Kidney disease 1= Yes 2= No 12. Depression 1= Yes 2= No

3.6 Data Analysis

All analyses were conducted using SPSS version 27 with the Complex Samples module that incorporated the stratum, primary sampling units, and weights to account for complex sample design and provide appropriate population estimates. SPSS Complex Samples can compute statistics and standard errors from complex sample by incorporating the designs into survey analysis (SPSS, 2020). Since all variables in this study are from the core-only section, variable _LLCPWT was used for weighting, _STSTR for stratification and _PSU for primary sampling unit (CDC, 2020).

3.6.1 Descriptive Statistics

Descriptive statistics such as means, standard deviations, frequencies and weighted percentages were calculated for all variables including PA, HRQoL, sex, age, race/ethnicity, education, marital, income, employment, alcohol consumption, BMI, smoking and comorbidities. Pearson chi-square test of independence was conducted to determine if there were

any relationships between HRQoL and PA categories and the sex differences on demographic and characteristics of participants. To further determine the relationships between PA categories and HRQoL, post-hoc test was applied by conducting six 2×2 chi-square tests. Thus, an adjusted α level (0.05/6 = 0.0083) was set for the post-hoc test.

3.6.2 Primary Analysis

Binomial logistic regression is an appropriate technique to apply in this study as it allows for the exploration of several predictor variables that are either nominal or ordinal in correlation with the dichotomous dependent variables of HRQoL (Urdan, 2016). An alternative statistical procedure for analyzing categorical dependent variable is discriminant analysis. However, logistic regression is preferred because it does not assume multivariate normality of independent variables (Tabachnick & Fidell, 2013). Furthermore, logistic regression does not assume that there is linearity between the independent and dependent variables. Finally, logistic regression does not require the assumption of equal variance (homoscedasticity; Tabachnick & Fidell, 2013). Using logistic regression analysis allows to examine the direction, and magnitude of the relationships between PA and HRQoL (Tabachnick & Fidell, 2013).

The assumptions of logistic regression were examined: 1) binary dependent variable, 2) large sample size, 3) absence of multicollinearity, and 4) independence of error terms (Statistics Solutions, 2018). To diagnose multicollinearity, the most commonly used method is examining the correlation matric of explanatory variables (Alin, 2010). However, as correlation and collinearity are different, multicollinearity can still exist even when all correlations are low (Alin, 2010). Another diagnostic approach for multicollinearity is determinant of R. Similar to correlation, there still might be multicollinearity even though determinant is very close to 1 (Alin, 2010). Variance inflation factor (VIF) is widely used in diagnosis of multicollinearity

(Alin, 2010). VIF is frequently used for quantitative continuous explanatory variables. When predictors are categorical variables, dummy variables are created in order to apply regression analysis (Wissmann et al., 2011). Yet, the outcome and interpretation of dummy variables may be different from the cases of quantitative continuous variables. Additionally, using dummy variable to assess multicollinearity is still unexplored or only partially explored in the literature (Wissmann et al., 2011). Meanwhile, previous research has calculated VIF for categorical predictors to examine absence of multicollinearity (Welch, 2019; Valderranma, 2019). Therefore, the linear regression function in SPSS was applied to determine the relationships among predictor variables. The VIF was calculated for each predictor to explore the existence of multicollinearity.

Multiple unadjusted and adjusted binomial logistic regression models were used to examine the relationships between meeting PA guidelines (meeting both aerobic activity and MSA guidelines, meeting aerobic activity only, meeting MSA guideline only, meeting neither) and the odds of having poor HRQoL (general health, physical health, mental health, and activity limitation). Because age, sex, race/ethnicity, education, marital status, income, employment, alcohol consumption, BMI, smoking and comorbidities were found to be associated with HRQoL among older adults in previous studies (Xu et al., 2018; Etxeberria et al., 2019; Skarupski et al., 2007; Huguet et al., 2008; Bielderman et al., 2015; Kim et al., 2018; Yan et al., 2004; Gasperini et al., 2017; Kaplan et al., 2012), they were controlled for in the adjusted logistic regression models. Insignificant covariates were then excluded for model comparison. Three models (i.e., PA only, PA + all covariate, PA + significant covariates) were compared by computing the difference in model chi-square. Odds ratio (OR) was used as the index of effect size. OR is the predominant index of effect size used to demonstrate increased risk for disease in

epidemiological studies (Bland & Altman, 2000). At a 5% disease rate in the nonexposed group, *OR* = 1.52, 2.74, and 4.72 are reference points of a small, medium, and large effect size, respectively (Chen et al., 2010).

To investigate the moderation effects of sex, an interaction term PA*sex was entered into the logistic regression models. Difference in model chi-square was calculated between the moderated model and the old model for model comparison.

CHAPTER IV: RESULTS

4.1 Descriptive analysis

Data from 87,495 older adults (mean age 72.58± 0.04 years) were included in the analysis. Table 4.1 shows the summary of study participants' characteristics. The most frequently reported age range was 65-69 years (33.7%). Majority of the participants were non-Hispanic white (78.1%), retired (72.6%), and not a heavy drinker (95.3%). Slightly more than half were identified as female (51.2%), married/unmarried couples (58.5%), never smoked (50.1%), and having at least 3 chronic diseases (56.6%). Participants most frequently reported having an income level greater than $50,000 (44.8%) and being overweight (39.4%). More than a third (37.4%) received high school education or lower. Regarding meeting PA guidelines, 33.8% met neither guideline, 8.8% met MSA guideline only, 32.9% met aerobic activity guideline only, and 24.6% met both guidelines (see Figure 3). For the HRQoL components, 23% had poor general health, and 15.8%, 7.5%, 9.3% reported frequent days of poor physical health, mental health and activity limitation, respectively (see Figure 4).

Table 4. 1

Demographics and characteristics of participants

	N	Weighted %
Total	87,495	100%
Age		
65-69	28,571	33.7%
70-74	25,121	29.0%
75-79	16,638	18.8%
≥80	17,165	18.4%
Sex		
Male	40,147	48.8%
Female	47,348	51.2%
Race		
White, non-Hispanic	74,981	78.1%
Black, non-Hispanic	5,022	8.3%
Other race, non-Hispanic	2,843	4.0%
Multiracial, non-Hispanic	1,146	0.9%
Hispanic	3,503	8.7%
Education		
Did not graduate high school	4,698	11.1%
Graduated high school	22,225	26.3%
Attended college/technical	23,977	31.5%
Graduated college	36,595	31.1%
Marital status		
Married/unmarried couple	47,155	58.5%
Never married	4,822	4.8%
Separated /Divorced/Widowed	35,518	36.6%
Employment status		
Employed	16,412	18.6%
Unemployed	961	1.2%
Homemaker	2,845	3.5%
Student	75	0.1%
Retired	6,4107	72.6%
Unable to work	3,095	4.0%
Income level		
Less than $15,000	6,773	9.1%
$15,000 to less than $25,000	15,233	18.0%
$25,000 to less than $35,000	11,115	12.3%
$35,000 to less than $45,000	14,759	15.9%
$50,000 or more	39,615	44.8%
BMI (kg/m^2)		
Underweight (< 18.5)	1,301	1.5%
Normal weight (18.5-25)	25,509	28.7%
Overweight (25-30)	33,846	39.4%
Obese (≥30)	26,839	30.4%
Smoking status		
Current (daily)	5,276	6.4%
Current (some days)	1,980	2.4%
Former smoker	34,550	41.1%

Table 4. 1 (cont'd)

Never smoked	45,689	50.1%
Heavy drinker		
No	83,311	95.3%
Yes	4,184	4.7%
Comorbidities (no. of diseases)		
0	6,590	7.6%
1	13,281	15.5%
2	18,213	20.4%
≥3	49,411	56.6%
PA guidelines		
Meeting both	22,124	24.6%
Meeting aerobic activity only	28,772	32.9%
Meeting MSA only	8,006	8.8%
Meeting neither	28,593	33.8%
General health		
Good (good, very good, or excellent health)	69,188	77.0%
Poor (poor or fair)	18,307	23.0%
Physical health (unhealthy days)		
Infrequent (<14 days/month)	73,737	84.2%
Frequent (≥14 days/month)	13,758	15.8%
Mental health (unhealthy days)		
Infrequent (<14 days/month)	81,174	92.5%
Frequent (≥14 days/month)	6,321	7.5%
Activity limitation (days)		
Infrequent (<14 days/month)	79,406	90.7%
Frequent (≥14 days/month)	8,089	9.3%

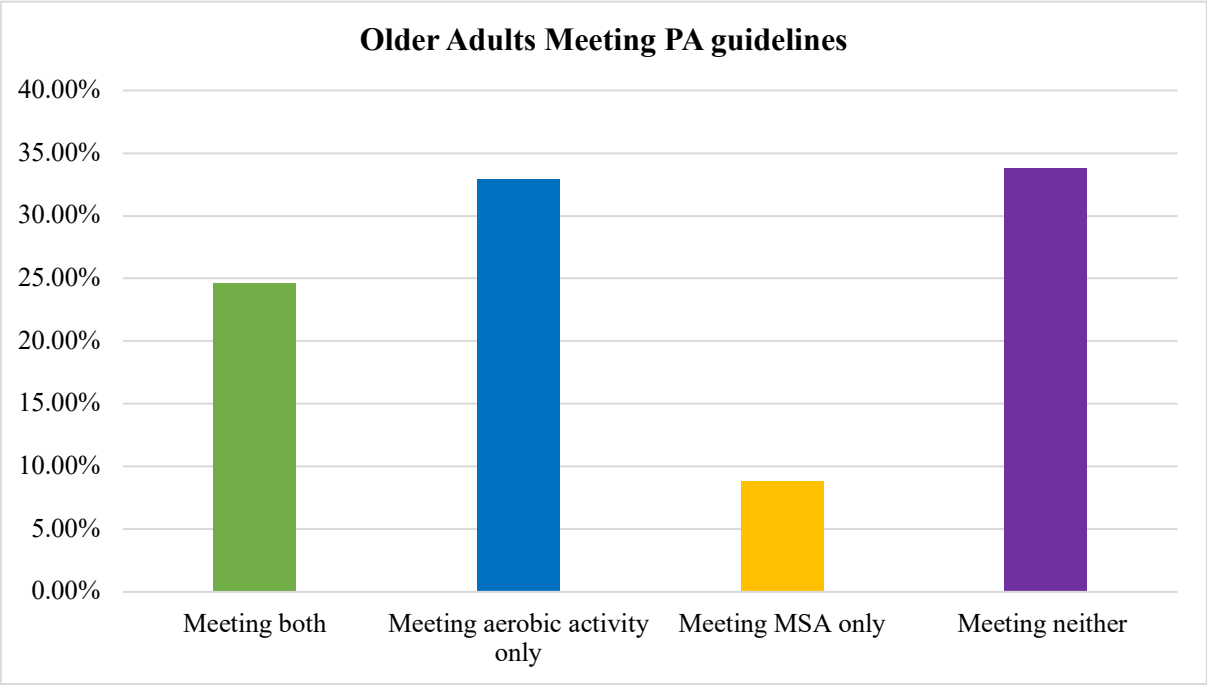

Figure 3. *Older Adults Meeting PA Guidelines*

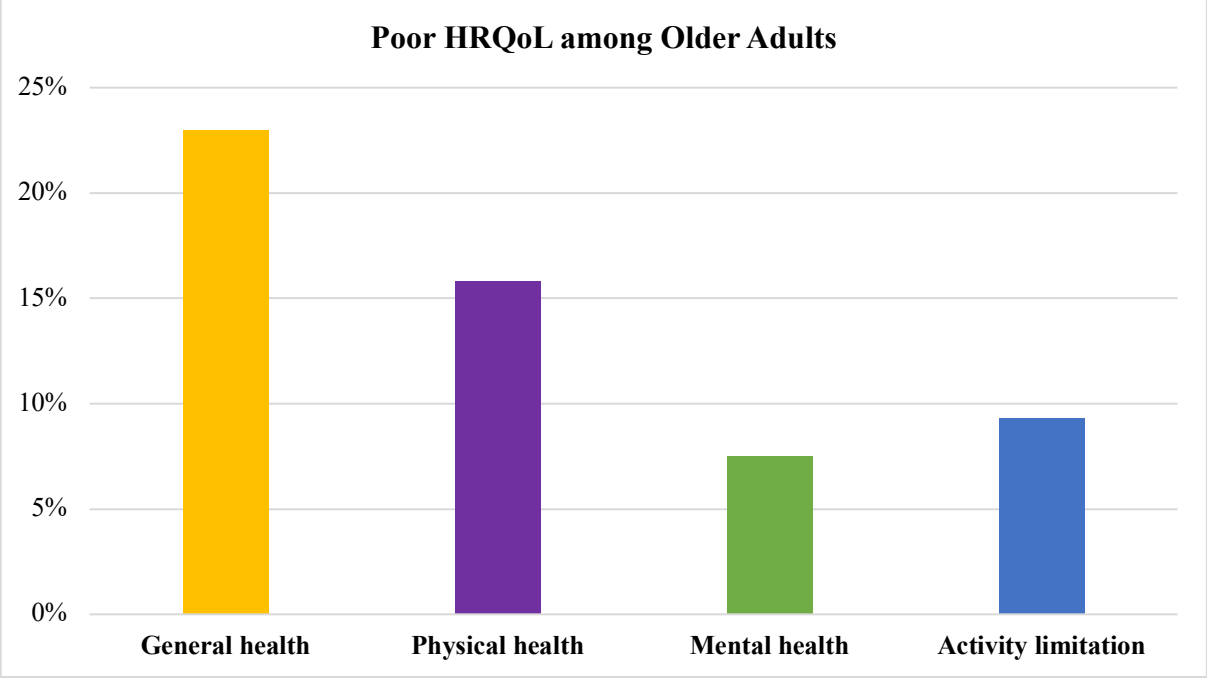

Figure 4. *Poor HRQoL among Older Adults*

Table 4.2 presents the prevalence of poor HRQoL by categories of meeting PA guidelines. There was a statistically significant association between PA categories and each component of HRQoL: (1) general health, $\chi^2(3) = 4585.30$, $p < .001$; (2) physical health, $\chi^2(3) = 2841.20$, $p < .001$; (3) mental health, $\chi^2(3) = 1055.22$, $p < .001$ (4) activity limitation, $\chi^2(3) = 2574.79$, $p < .001$. Respondents meeting both aerobic activity and MSA guidelines had the lowest prevalence of poor general health (14.1%) and poor mental health (4.6%) compared to other three PA groups. Compared to meeting aerobic activity guideline only, participants who met MSA only were more likely to report poor general (30%), physical health (24.2%), mental health (8.7%), and activity limitation (15.4%). Older adults who met neither PA guidelines had the highest prevalence of poor general (35.1%) and mental health (11.3%; see Figure 5).

Table 4.3 shows the results of post hoc test for Chi-square. Respondents meeting both aerobic activity and MSA guidelines had significantly lower prevalence of all components of poor HRQoL (i.e., general health, physical health, mental health, activity limitation) compared to people meeting MSA guideline only or meeting neither guideline, $p < .001$. By contrast, no significant difference was found between participants who met both guidelines and those meeting aerobic activity guideline only, $p > .0083$. Compared to individuals meeting MSA only or meeting neither guideline, individuals achieving aerobic activity guideline had significantly lower percentages of reporting poor HRQoL across all four domains, $p < .001$. Similarly, there was significant difference in reporting poor general health and mental health between persons meeting MSA guideline only and those who met neither guideline, $p < .001$. However, no significant difference was found between people meeting MSA only and those who met neither guideline, regarding the prevalence of poor physical health and activity limitation, $p > .083$.

Table 4. 2

Poor HRQoL by meeting PA guidelines

PA Guidelines	Fair/Poor General Health	Frequent Physical Unhealthy Days	Frequent Mental Unhealthy Days	Frequent Activity Limitation Days
Meeting both	14.1%	10.4%	4.6%	5.1%
Meeting aerobic activity only	15.3%	10.0%	5.4%	5.0%
Meeting MSA only	30.0%	24.2%	8.7%	15.4%
Meeting neither	35.1%	23.3%	11.3%	15.1%
χ^2	4585.30	2841.20	1055.22	2574.79
p	<.001	< .001	<.001	<.001

Table 4. 3

Post-hoc tests of poor HRQoL by meeting PA guidelines

PA Guidelines	Fair/Poor General Health *P* value	Frequent Physical Unhealthy Days *P* value	Frequent Mental Unhealthy Days *P* value	Frequent Activity Limitation Days *P* value
Meeting both vs. meeting aerobic activity only	.095	.451	.049	.953
Meeting both vs. meeting MSA only	<.001	<.001	<.001	<.001
Meeting both vs. meeting neither	<.001	<.001	<.001	<.001
Meeting aerobic activity only vs. meeting MSA only	<.001	<.001	<.001	<.001
Meeting aerobic activity only vs. meeting neither	<.001	<.001	<.001	<.001
Meeting MSA only vs. meeting neither	<.001	.475	<.001	.746

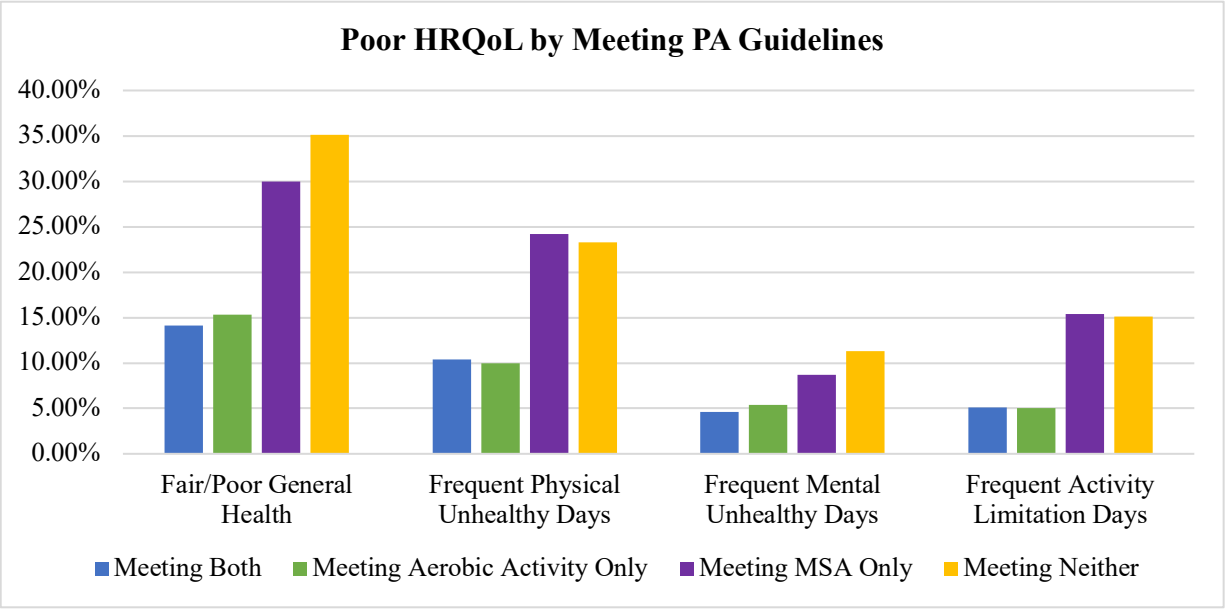

Figure 5. *Poor HRQoL by Meeting PA Guidelines*

Table 4.4 presents participants' characteristics by sex. Older men and women differed significantly in the following variables: (1) age, $\chi^2(3) = 133.35$, $p < .001$; (2) education, $\chi^2(3) = 675.56$, $p < .001$; (3) marital status, $\chi^2(2) = 5054.04$, $p < .001$; (4) employment status, $\chi^2(5) = 3283.76$, $p < .001$; (5) income level, $\chi^2(4) = 1608.24$, $p < .001$; (6) BMI, $\chi^2(3) = 1317.56$, $p < .001$; (7) smoking status, $\chi^2(3) = 1941.23$, $p < .001$; (8) meeting PA guidelines, $\chi^2(3) = 686.63$, $p < .001$; (9) physical health, $\chi^2(1) = 44.22$, $p = .001$; (10) mental health, $\chi^2(1) = 182.19$, $p < .001$; and (11) activity limitation, $\chi^2(1) = 16.94$, $p = .04$. There were no statistically significant differences in race, heavy drinker, comorbidities, and general health between male and female participants.

Significantly more men were aged 65-69 years (34.6%), married/unmarried couple (70.2%), employed (22.1%), overweight (44.6%), former smokers (48.3%), attended graduated college (34.7%), had an income level of $50,000 or more (51.5%) than women. By contrast, female respondents were more likely to be aged 80 years and above (19.7%),

separated/divorced/widowed (47.8%), homemakers (6.7%), have normal weight (32.5%), attended college/technical (33.8%), have an annual income within $15,000 to $25,000 (20.7%), and never smoked (57.0%) than male participants.

With respect to meeting PA guidelines, 29.8% men met neither guideline, 8.6% met MSA guideline only, 34.3% met aerobic activity guideline only, and 27.2% met both guidelines. Compared to men, more women met neither guideline (37.5%) and fewer women met aerobic activity only (31.5%) and both PA guidelines (22%). Similar to men, only 8.9% of women met MSA guideline only (see Figure 6). With regard to HRQoL domains, 23.4% male respondents reported poor general health, 15% had poor physical health, 6.3% had poor mental health, and 8.9% had frequent days of activity limitation. There was no sex difference in having poor general health. Nevertheless, a significantly higher percentage of women reported poor physical health (16.6%), mental health (8.7%), and activity limitation (9.7%) compared to men (see Figure 7).

Table 4. 4

Demographics and characteristics of participants by sex

	Males		Females			
	N	Weighted %	*N*	Weighted %	χ^2	*p*
Total	40,147	100%	47,348	100%		
Age					133.35	<.001
65-69	13,574	34.6%	14,997	32.8%		
70-74	11,814	29.9%	13,307	28.2%		
75-79	7,542	18.4%	9,096	19.2%		
≥80	7,217	17.1%	9,948	19.7%		
Race					29.12	.386
White, non-Hispanic	34,866	78.5%	40,115	77.7%		
Black, non-Hispanic	1,886	7.9%	3,136	8.7%		
Other race, non-Hispanic	1,342	4.1%	1,501	4.0%		
Multiracial, non-Hispanic	525	0.8%	621	1.0%		
Hispanic	1,528	8.7%	1,975	8.6%		
Education					675.56	<.001
Did not graduate high school	2,146	11.9%	2,552	10.3%		
Graduated high school	9,185	24.3%	13,040	28.3%		
Attended college/technical	9,946	29.1%	14,013	33.8%		
Graduated college	18,852	34.7%	17,743	27.7%		
Marital status					5054.04	<.001
Married/unmarried couple	26,490	70.2%	20,665	47.4%		
Never married	2,315	4.9%	2,507	4.8%		
Separated /Divorced/Widowed	11,342	25%	24,176	47.8%		
Employment status					3283.76	<.001
Employed	9,090	22.1%	7,322	15.3%		
Unemployed	421	1.0%	540	1.3%		
Homemaker	39	0.2%	2,806	6.7%		
Student	27	0.0%	48	0.1%		
Retired	29,395	73.1%	34,712	72.2%		
Unable to work	1,175	3.5%	1,920	4.4%		
Income level					1608.24	<.001
Less than $15,000	2,240	7.2%	4,533	10.8%		
$15,000 to less than $25,000	5,384	15.1%	9,849	20.7%		
$25,000 to less than $35,000	4,318	10.7%	6,797	13.8%		
$35,000 to less than $45,000	6,638	15.9%	8,121	15.9%		
$50,000 or more	21,567	51.1%	18,048	38.8%		
BMI (kg/m^2)					1317.56	<.001
Underweight (< 18.5)	284	0.8%	1,017	2.2%		
Normal weight (18.5-25)	9,761	24.7%	15,748	32.5%		
Overweight (25-30)	17,866	44.6%	15,980	34.5%		
Obese (≥30)	12,236	30.0%	14,603	30.8%		
Smoking status					1941.23	<.001
Current (daily)	2,531	6.6%	2,745	6.2%		
Current (some days)	853	2.2%	1,127	2.5%		
Former smoker	19,048	48.3%	15,502	34.2%		
Never smoked	17,715	42.9%	27,974	57.0%		
Heavy drinker					0.56	0.695
No	38,162	95.4%	45,149	95.3%		

Table 4. 4 (cont'd)

Yes	19,85	4.6%	2,199	4.7%		
Comorbidities (no. of diseases)					15.22	0.346
0	3,054	7.5%	3,536	7.6%		
1	6,063	15.7%	7,218	15.2%		
2	8,076	19.9%	10,137	20.9%		
≥3	22,954	56.9%	26,457	56.3%		
PA guidelines					686.63	<.001
Meeting both	10,972	27.2%	11,152	22.0%		
Meeting aerobic activity only	14,042	34.3%	14,730	31.5%		
Meeting MSA only	3,529	8.6%	4,477	8.9%		
Meeting neither	11,604	29.8%	16,989	37.5%		
General health					11.67	0.109
Good (good, very good, or excellent health)	31,685	76.6%	37,503	77.5%		
Poor (poor or fair)	8,462	23.4%	9,845	22.5%		
Physical health (unhealthy days)					44.22	0.001
Infrequent (<14 days/month)	34,210	85.0%	39,527	83.4%		
Frequent (≥14 days/month)	5,937	15.0%	7,821	16.6%		
Mental health (unhealthy days)					182.19	<.001
Infrequent (<14 days/month)	37,829	93.7%	43,345	91.3%		
Frequent (≥14 days/month)	2,318	6.3%	4,003	8.7%		
Activity limitation (days)					16.94	0.04
Infrequent (<14 days/month)	36,710	91.1%	42,696	90.3%		
Frequent (≥14 days/month)	3,437	8.9%	4,652	9.7%		

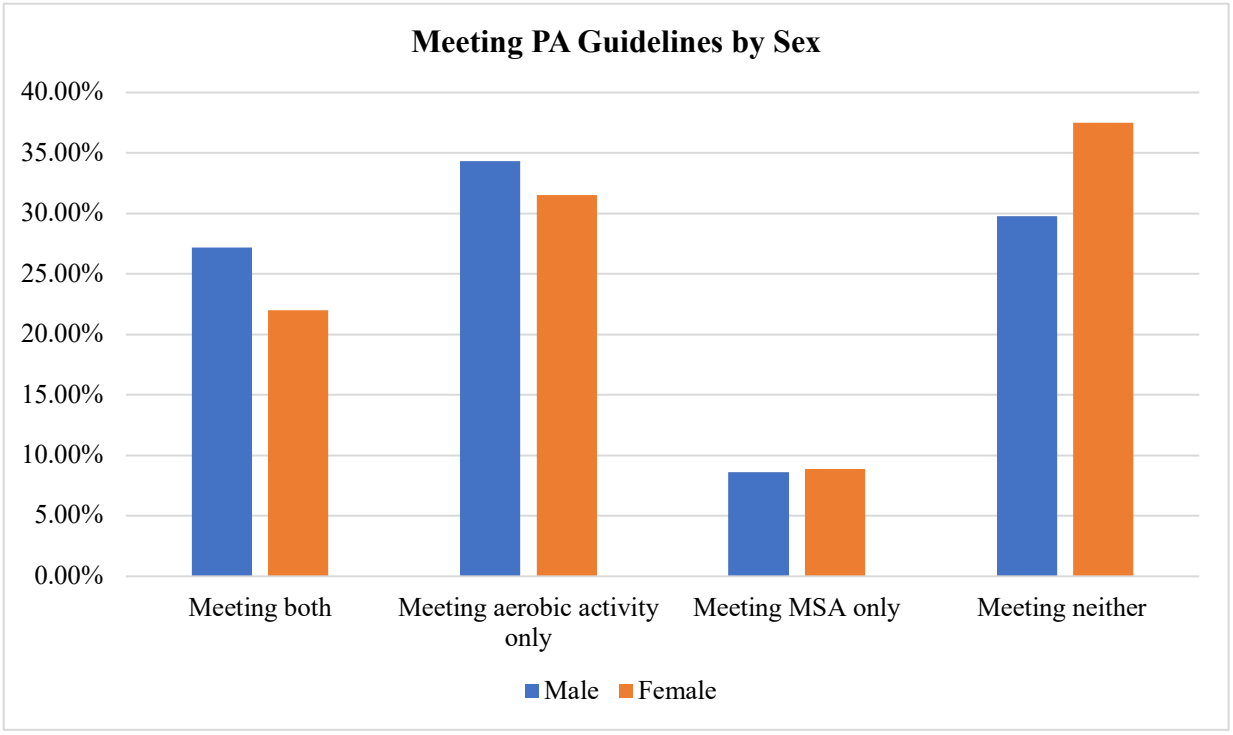

Figure 6. *Meeting PA guidelines by sex*

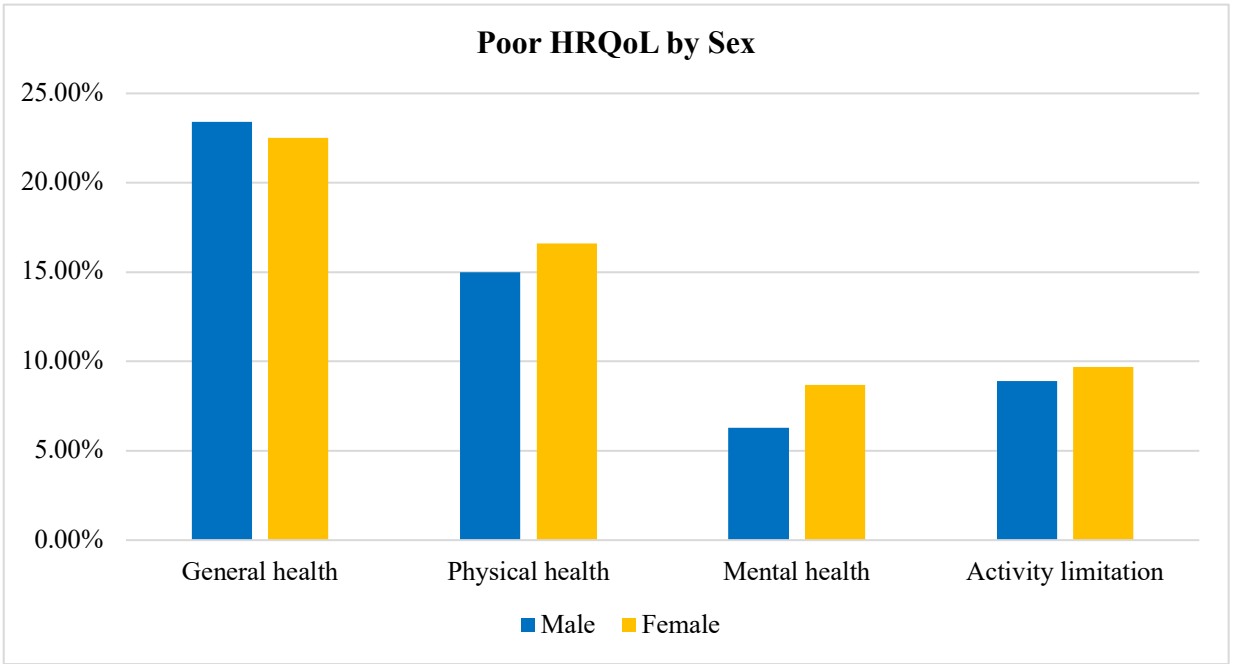

Figure 7. *Poor HRQoL by Sex*

Table 4.5 provides results on the prevalence of poor HRQoL by categories of meeting PA guidelines. Male and female respondents meeting neither PA guidelines had the highest prevalence of poor general health (36.7% for males, 33.8% for females), followed by meeting MSA guideline only (29.1% for males, 30.9% for females), meeting aerobic activity guideline only (16.9% for males, 13.50% for females), and meeting both guidelines (15.3% for males, 12.6% for females; see Figure 8). For physical health domain of HRQoL, men and women meeting aerobic activity guideline only had the lowest prevalence of poor physical health (9.7% for males, 10.3% for females) than the other three PA groups and those meeting MSA guideline only were most likely to report poor physical health (23.4% for males, 24.8% for females) compared to the other three PA groups (see Figure 9) .

Figure 10 depicts the prevalence of poor mental health by meeting PA guidelines in males and females. The prevalence of having poor mental health from the highest to the lowest was consistent in male and female respondents: meeting neither guideline (10.1% for males, 12.1% for females), meeting MSA guideline only (8.2% for males, 9.0% for females), meeting aerobic activity guideline only (4.3% for males, 6.7% for females), and meeting both guidelines (3.9% for males, 5.4% for females). Regarding activity limitation domain of HRQoL, there was sex difference in the prevalence trend within the four PA groups. Although both men and women who met the MSA guideline only reported the highest prevalence of having frequent activity limitation days (15.6% for males, 15.2% for females), male respondents meeting both guidelines had the lowest prevalence of having frequent limitation days (4.9%) whereas female participants who met aerobic activity guideline only reported least frequent limitation days (5.0%; see Figure 11).

Table 4. 5

Sex Difference on Poor HRQoL by Meeting PA Guidelines

PA Guidelines	Fair/Poor General Health		Frequent Physical Unhealthy Days		Frequent Mental Unhealthy Days		Frequent Activity Limitation Days	
	Male	Female	Male	Female	Male	Female	Male	Female
Meeting Both	15.3%	12.6%	9.9%	11.1%	3.9%	5.4%	4.9%	5.2%
Meeting Aerobic Activity Only	16.9%	13.5%	9.7%	10.3%	4.3%	6.7%	5.0%	5.0%
Meeting MSA Only	29.1%	30.9%	23.4%	24.8%	8.2%	9.0%	15.6%	15.2%
Meeting Neither	36.7%	33.8%	23.3%	23.2%	10.1%	12.1%	15.1%	15.0%

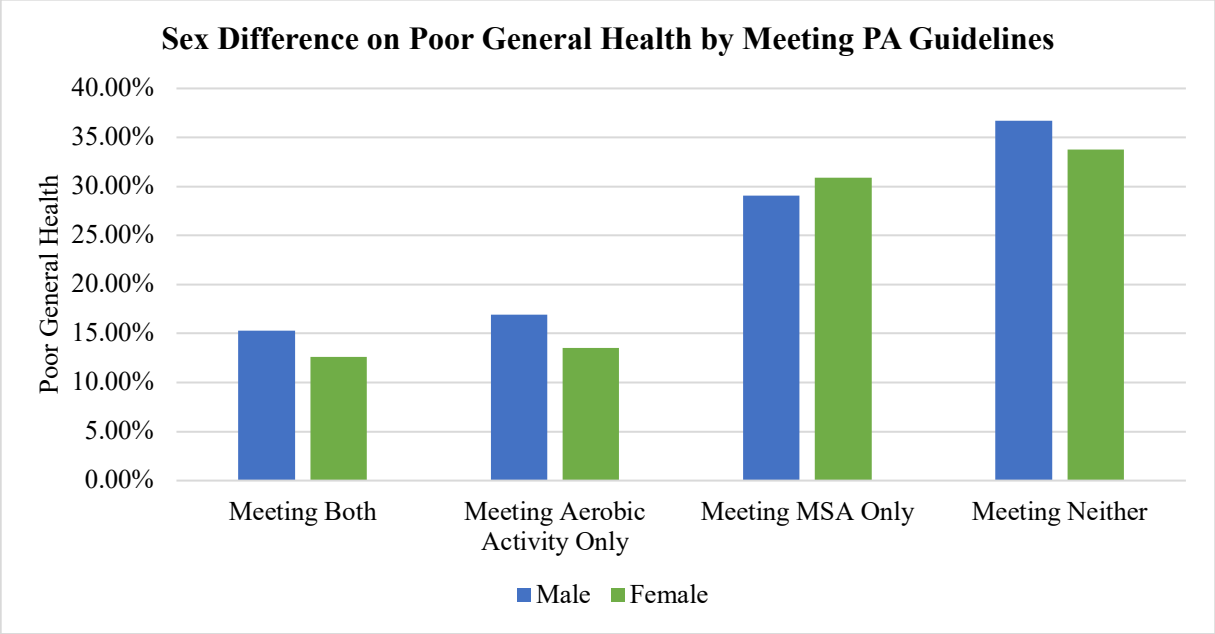

Figure 8. *Sex Difference on Poor General Health by Meeting PA Guidelines*

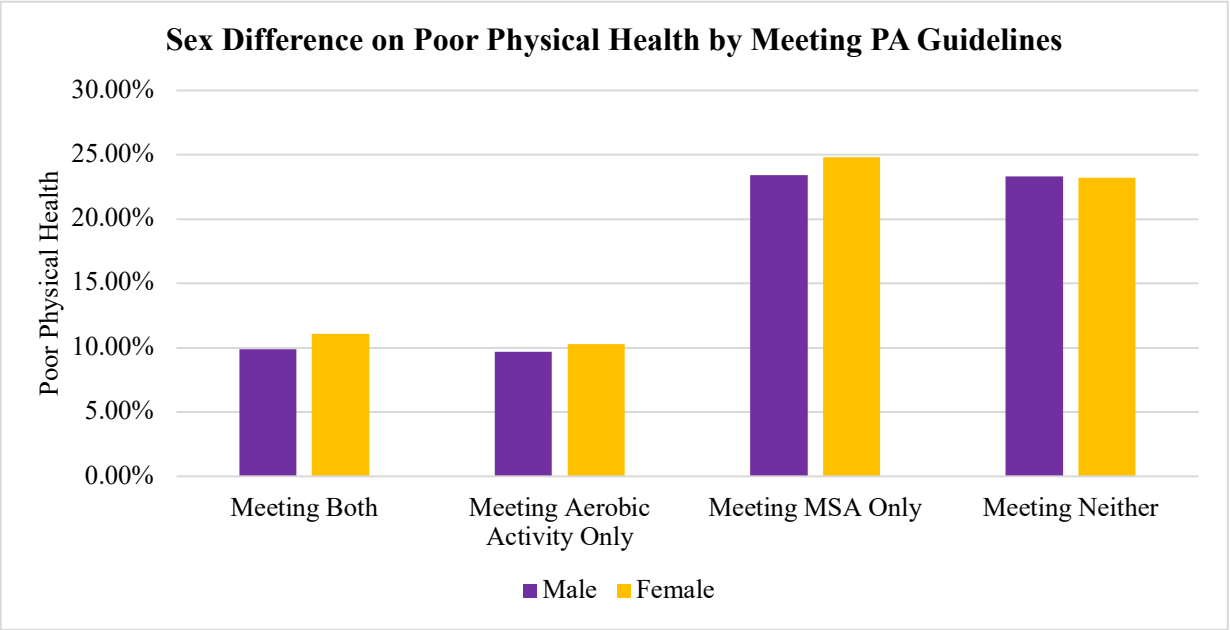

Figure 9. *Sex Difference on Poor Physical Health by Meeting PA Guidelines*

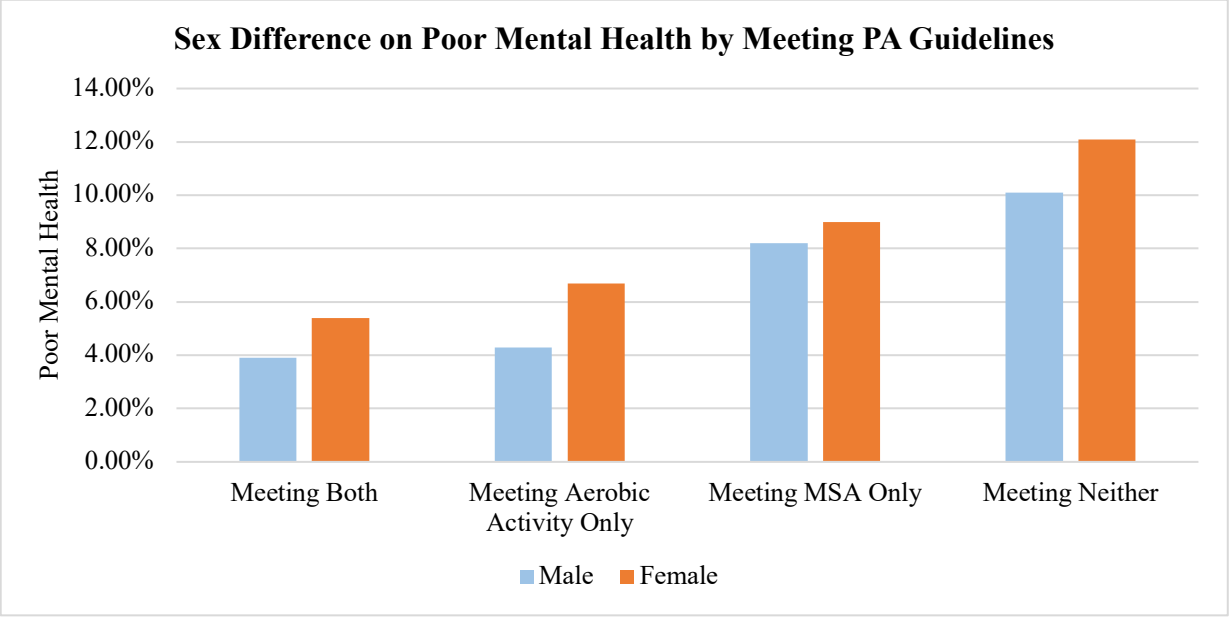

Figure 10. *Sex Difference on Poor Mental Health by Meeting PA Guidelines*

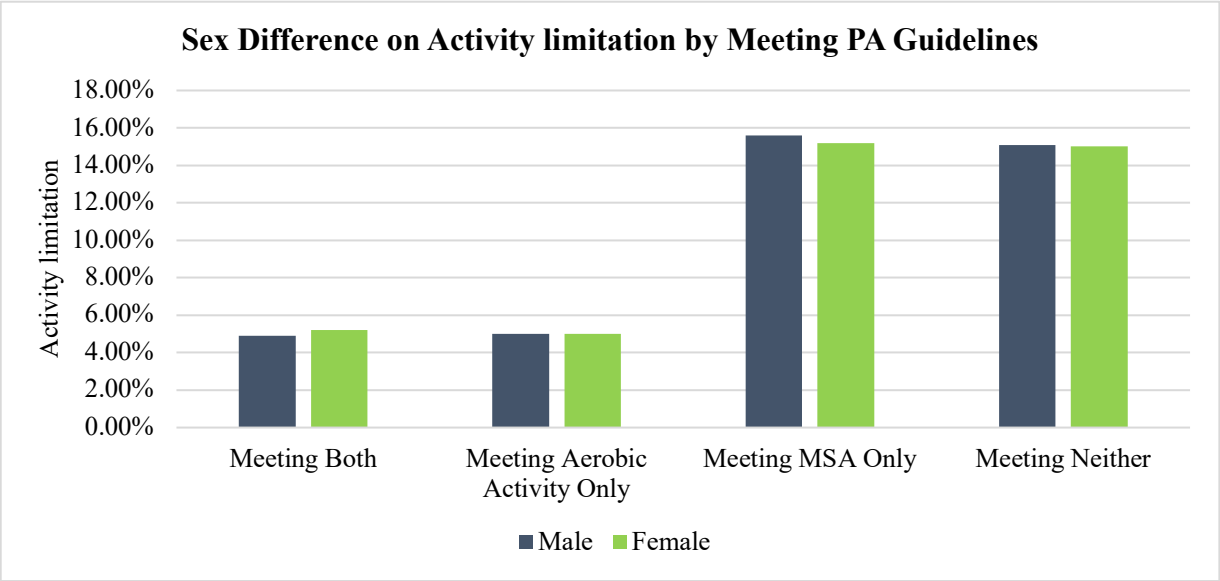

Figure 11. *Sex Difference on Activity Limitation by Meeting PA Guidelines*

Table 4.6 provides comparison of demographics for complete and missing case. There were significant differences in all key demographic variables between complete and missing case: (1) age, $\chi^2(3) = 1647.13$, $p < .001$; (2) sex, $\chi^2(1) = 1453.31$, $p < .001$; (3) race, $\chi^2(5) = 5005.03$, $p < .001$; (4) education, $\chi^2(4) = 3306.68$, $p < .001$; and (5) marital status, $\chi^2(3) = 2071.10$, $p < .001$. Compared to complete case, significant more participants were aged 80 years and above (27.9%), females (63.8%), non-Hispanic black (6.6%), with high school education or lower (40.4%), and separated/divorced/widowed (46.1%) in missing case.

Table 4. 6

Comparison of demographics for complete and missing case

	Complete		**Missing**			
	N	%	*N*	%	χ^2	*p*
Total	87,495	100%	67,206	100%		
Age					1647.13	<.001
65-69	28,571	32.7	18,580	27.6		
70-74	25,121	28.7	16,732	24.9		
75-79	16,638	19.0	13,139	19.6		
≥80	17,165	19.6	18,754	27.9		
Sex					1453.31	<.001
Male	40,147	45.9	24,358	36.2		
Female	47,348	54.1	42,848	63.8		

Table 4. 6 (cont'd)

Race					5005.03	<.001
White, non-Hispanic	74,981	85.7	53,354	79.4		
Black, non-Hispanic	5,022	5.7	4,404	6.6		
Other race, non-Hispanic	2,843	3.2	2.228	3.3		
Multiracial, non-Hispanic	1,146	1.3	857	1.3		
Hispanic	3,503	4.0	2,690	4.0		
Don't know/Not sure/Refused			3,672	5.5		
Education					3306.68	<.001
Did not graduate high school	4,698	5.4	6,454	9.6		
Graduated high school	22,225	25.4	20,680	30.8		
Attended college/technical	23,977	27.4	18,143	27.0		
Graduated college	36,595	41.8	21,237	31.6		
Don't know/Not sure/Missing	0	0	692	1.0		
Marital status					2071.10	<.001
Married/unmarried couple	47,155	53.9	31,398	46.7		
Never married	4,822	5.5	3,744	5.6		
Separated /Divorced/Widowed	35,518	40.6	30,951	46.1		
Refused	0	0	1,092	1.6		

4.2 Logistic regression

4.2.1 Logistic regression assumptions

4.2.1.1 Binary dependent variable

Binary logistic regression assumes that the dependent variable is dichotomous. This requirement was met since the dependent variable HRQoL in this study was coded as poor vs. good or infrequent vs. frequent unhealthy days.

4.2.1.2 Large sample size

Logistic regression models with maximum likelihood (ML) estimates requires a minimum of 10 cases per independent variable (Hosmer et al., 2013). This study's dataset included 20 variables with 87,495 respondents, meeting the sample size assumption.

4.2.1.3 Absence of multicollinearity

Logistic regression assumes that there are no strong correlations among independent variables. This assumption was evaluated by the VIF. A VIF greater than 5 indicates moderate

multicollinearity, and a VIF greater than 10 suggests a strong multicollinearity, violating the assumption (Menard, 2010). As seen in Table 4.7, the VIFs for all predictor variables were below 2, indicating the assumption of absence of multicollinearity was met.

Table 4. 7

Multicollinearity Tests

Variable	VIF
Age	1.14
Sex	1.10
Race	1.06
Education	1.31
Marital status	1.29
Employment status	1.09
Income level	1.58
BMI	1.11
Smoking status	1.09
Heavy drinker	1.02
Comorbidities	1.09
PA	1.10

4.2.1.4 Independence of error terms

Logistic regression requires each observation to be independent and does not come from pre and post measurements or matched data. The BRFSS did not use repeated measures and each participant's response was independent of other individuals' responses; therefore, this assumption was met.

4.2.2 Model comparison

Table 4.8 presents three different models (PA only, PA + all covariates, PA+ significant covariates only) for each outcome variables. For general health component of HRQoL, adding all covariates to the model significantly improved the PA only model, χ^2 = 3196.77-952.32 = 2244.45 with df = 32, $p < .001$. Moreover, the difference between the model excluding insignificant covariates (i.e., age, marital status, heavy drinker) and the full model was χ^2 =3196.77-3166.56 =30.21, df = 6, $p < .001$, indicating that the full model significantly enhanced prediction of poor general health. Thus, the model including all covariates was retained.

For physical health component of HRQoL, the difference between the PA only model and the model with all covariates was χ^2 = 1754.59-612.42= 1142.17, df =32, $p < .001$. This suggested statistically significant enhancement in model by adding all covariate. Additionally, model run with insignificant covariates (i.e., age, sex, marital status, heavy drinker) omitted was not statistically different from the full model, χ^2 = 1754.59-1740.98 = 13.61, df = 7, $p = .059$. Therefore, the more parsimonious model with significant covariates only was chosen.

Regarding mental health domain of HRQoL, the full model fit the data significantly better than the model with PA only, χ^2 = 1084.46-211.40= 873.06, df = 32, $p < .001$. Since all covariates were significant in the full model, the model including all covariates were determined as the best fit model.

With respect to activity limitation component of HQoL, there was significant improvement in model with all covariates compared to the PA only model, χ^2 = 1726.17-560= 1166.17, df = 32, $p < .001$. After removing insignificant covariates (i.e., sex, marital status, heavy drinker), the model was significantly different from the full model, χ^2 = 1726.17-1687.81= 38.36, df = 4, $p < .05$. This indicated that the model with all covariates had the best fit.

Table 4. 8

Comparison of logistic regression models

HRQoL	**Variables**	**df**	**Model Chi-Square**
General health	PA only	3	952.32
	PA+ all covariates	35	3196.77
	PA+ significant covariates only	29	3166.56
Physical health	PA only	3	612.42
	PA+ all covariates	35	1754.59
	PA+ significant covariates only	28	1740.98
Mental health	PA only	3	211.40
	PA+ all covariates	35	1084.46
Activity limitation	PA only	3	560
	PA+ all covariates	35	1726.17
	PA+ significant covariates only	31	1687.81

4.2.3 Adjusted logistic regression

4.2.3.1 General Health

The logistic regression model was statistically significant, χ^2 (35) = 3196.77, $p < .001$, suggesting that the relationship between general health and predictors included in this model was statistically significant. The model explained about 28.5% (Nagelkerke R^2) of the variance in general health. The classification table showed that 79.8% of cases were correctly classified with 94.9% for good general health and 29.2% for poor general health.

Table 4.9 shows the adjusted odds ratios and 95% confidence intervals (CI) for all predictors of general health among older adults. Compared to those meeting neither guideline, the odds of having poor general health decreased by 55% in participants meeting both aerobic activity and MSA guidelines (OR= 0.45, 95% CI: 0.40-0.51), by 57% in respondents meeting aerobic guideline only (OR= 0.43, 95% CI: 0.39-0.48), and by 13% in those meeting MSA only (OR= 0.87, 95% CI: 0.76-0.99), after adjusting for all social-demographic and behavior factors. Table 4.10 provides the results of additional comparison between different PA categories. There was no statistical difference in the odds of poor general health between participants meeting both guidelines and those meeting aerobic activity guideline only. Nevertheless, compared to meeting MSA guideline only, the odds of having poor general health was significantly lower in respondents who met both aerobic activity and MSA guidelines (OR= 0.52, 95% CI: 0.45-0.60), and those who met aerobic activity guideline only (OR= 0.50, 95% CI: 0.44-0.57).

Compared to women, men were 35% more likely to have poor general health (OR= 1.35, 95% CI: 1.24-1.47). The odds of having poor general health were significantly greater among non-Hispanic blacks (OR= 1.16, 95% CI: 1.01-1.33), and Hispanics (OR= 2.46, 95% CI: 2.08-2.90) than non-Hispanic whites. In general, as educational levels increased, the odds of reporting

poor general health decreased. Relative to employed respondents, there were significantly greater odds of reporting poor general health in respondents who were unemployed (OR=2.23, 95%: 1.64-3.08), homemaker (OR= 1.68, 95% CI: 1.33-2.11), retired (OR= 1.55, 95% CI:1.37-1.76), and unable to work (OR= 6.08, 95% CI: 4.96-7.45). Higher levels of income were associated with reduced odds of having poor general health. The odds of reporting poor general health were significantly greater in older adults who were underweight (OR= 2.03, 95% CI:1.58-2.61), and those who were obese (OR = 1.17, 95 % CI:1.06-1.30) in comparison to participants with normal weight. Both former and current smokers had significantly higher odds of reporting poor general health than individuals who never smoked. With increased number of comorbidities, there was a significant trend of greater odds of reporting poor general health with participants having 3 or more comorbidities revealing the highest odds (OR= 7.89, 95% CI: 6.13-10.06).

Table 4. 9

Adjusted binominal logistic regression for poor general health

Variables	Odds Ratio	95% Confidence Interval for Odds Ratio	
		Lower	*Upper*
PA Guidelines			
Meeting both	0.45*	0.40	0.51
Meeting aerobic activity only	0.43*	0.39	0.48
Meeting MSA only	0.87*	0.76	0.99
Meeting neither	1(Reference)		
Age			
65-69	1(Reference)		
70-74	1.01	0.91	1.11
75-79	1.12	1.00	1.26
≥80	0.99	0.88	1.12
Sex			
Male	1.35 *	1.24	1.47
Female	1(Reference)		
Race			
White, non-Hispanic	1(Reference)		
Black, non-Hispanic	1.16*	1.01	1.33
Other race, non-Hispanic	1.02	0.77	1.35
Multiracial, non-Hispanic	1.24	0.93	1.67
Hispanic	2.46*	2.08	2.90
Education			

Table 4. 9 (cont'd)

Did not graduate high school	1(Reference)		
Graduated high school	0.68*	0.59	0.79
Attended college/technical	0.62*	0.54	0.72
Graduated college	0.51*	0.44	0.59
Marital status			
Married/unmarried couple	1(Reference)		
Never married	0.91	0.76	1.09
Separated /Divorced/Widowed	0.99	0.90	1.09
Employment status			
Employed	1(Reference)		
Unemployed	2.23*	1.64	3.08
Homemaker	1.68*	1.33	2.11
Student	1.05	0.30	3.67
Retired	1.55*	1.37	1.76
Unable to work	6.08*	4.96	7.45
Income level			
Less than $15,000	1(Reference)		
$15,000 to less than $25,000	0.85	0.73	1.00
$25,000 to less than $35,000	0.71*	0.60	0.84
$35,000 to less than $45,000	0.55*	0.46	0.65
$50,000 or more	0.40*	0.34	0.47
BMI (kg/m^2)			
Underweight (< 18.5)	2.03*	1.58	2.61
Normal weight (18.5-25)	1(Reference)		
Overweight (25-30)	0.87*	0.79	0.97
Obese (≥30)	1.17*	1.06	1.30
Smoking status			
Current (daily)	1.41*	1.22	1.66
Current (some days)	1.53*	1.24	1.88
Former smoker	1.24*	1.13	1.35
Never smoked	1(Reference)		
Heavy drinker			
No	1(Reference)		
Yes	0.92	0.74	1.13
Comorbidities (no. of diseases)			
0	1(Reference)		
1	2.14*	1.61	2.86
2	2.67*	2.04	3.48
≥3	7.89*	6.13	10.06

*$p < 0.05$

Table 4. 10

Between group comparison of meeting physical activity guideline with regards to general health

Variables	**Odds Ratio**	**95% Confidence Interval for Odds Ratio**	
		Lower	***Upper***

Table 4. 10 (cont'd)

PA Guidelines			
Meeting both vs. Meeting aerobic activity only	1.04	0.93	1.17
Meeting aerobic activity only vs. Meeting MSA only	0.50*	0.44	0.57
Meeting both vs. Meeting MSA only	0.52*	0.45	0.60

The model adjusted for age, sex, race/ethnicity, education, marital status, employment status, income level, BMI, smoking status, heavy drinker, and comorbidities.
*$p < 0.05$

4.2.3.2 Physical health

The logistic regression model was statistically significant, χ^2 (28) = 1740.98, $p < .001$, indicating that the relationship between physical health and independent variables included in this model was statistically significant. The model explained about 16.7% (Nagelkerke R^2) of the variance in physical health. The overall correct classification rate was 84.7%, with 98.8% of the good physical health and 9.4% of the poor physical health being correctly predicted.

Table 4.11 provides the model based adjusted odds ratios and corresponding 95% CI for predictors of physical health in older adults. Compared to participants meeting neither guideline, the odds of reporting poor physical health were 48% lower in respondents meeting both aerobic activity and MSA guidelines (OR=0.52, 95% CI: 0.46-0.58), and 55% lower in those meeting aerobic activity only (OR=0.45, 95% CI: 0.41-0.50), after adjusting for race, education, employment status, income level, BMI, smoking status, and comorbidities. However, there was no significant difference when comparing individuals meeting MSA only to those meeting neither guideline. As seen in Table 4.12, the odds of reporting poor physical health were not statistically different in people meeting both PA guidelines and those meeting aerobic activity guideline only. Relative to persons meeting MSA guideline only, the odds of having poor physical health reduced by 60% in people who met aerobic activity guideline only (OR= 0.40, 95% CI: 0.34-0.47), and 55% in those meeting both guidelines (OR= 0.45, 95% CI: 0.39-0.54).

Non-Hispanic blacks had 28% lower odds of having poor physical health (OR= 0.72, 95% CI: 0.62-0.84) than non-Hispanic whites. By contrast, Hispanics had 33% higher odds of reporting poor physical health (OR= 1.33, 95% CI: 1.10-1.60) than non-Hispanic whites. The odds of having poor physical health were 23% greater in respondents who went to college/ technical school (OR= 1.23, 95% CI: 1.05-1.45) than those who did not graduate from high school. Compared to employed older people, there were higher odds of having poor physical health in those who were unemployed (OR= 1.96, 95% CI: 1.44-2.67), homemaker (OR= 1.59, 95% CI: 1.25-2.02), retired (OR= 1.71, 95% CI: 1.50-1.95), and unable to work (OR= 6.06, 95% CI: 4.98-7.46). In general, as income levels increase, the odds of having poor physical health decreased. The odds of reporting poor physical health increased by 64% in participants who were underweight (OR= 1.64, 95% CI: 1.21-2.24), and by 13% in those who were obese (OR= 1.13, 95% CI: 1.01-1.26) compared to older adults with normal weight. By contrast, elderly people who were overweight had 13% lower odds of having poor physical health (OR= 0.87, 95% CI: 0.78-0.98) than those who had normal weight. Relative to respondents who never smoked, the odds of reporting poor physical health were 26% higher in current daily smokers (OR= 1.26, 95% CI: 1.07-1.49), 32% greater in current smokers who smoke some days (OR= 1.32, 95% CI: 1.07-1.63), and 23% higher in former smokers (OR= 1.23, 95% CI: 1.13-1.34). As the number of comorbidities increased, there was a trend of higher odds of having poor physical health with respondents having 3 more comorbidities with the greatest odds (OR= 6.45, 95% CI: 5.11-8.14).

Table 4. 11

Adjusted binominal logistic regression for poor physical health

Variables	Odds Ratio	95% Confidence Interval for Odds Ratio	
		Lower	*Upper*
PA Guidelines			
Meeting both	0.52*	0.46	0.58
Meeting aerobic activity only	0.45*	0.41	0.50

Table 4. 11 (cont'd)

Meeting MSA only	1.14	0.99	1.32
Meeting neither	1(Reference)		
Race			
White, non-Hispanic	1(Reference)		
Black, non-Hispanic	0.72*	0.62	0.84
Other race, non-Hispanic	0.94	0.70	1.27
Multiracial, non-Hispanic	1.22	0.84	1.76
Hispanic	1.33*	1.10	1.60
Education			
Did not graduate high school	1(Reference)		
Graduated high school	1.02	0.87	1.20
Attended college/technical	1.23*	1.05	1.45
Graduated college	1.10	0.93	1.30
Employment status			
Employed	1(Reference)		
Unemployed	1.96*	1.44	2.67
Homemaker	1.59*	1.25	2.02
Student	0.34	0.10	1.14
Retired	1.71*	1.50	1.95
Unable to work	6.09*	4.98	7.46
Income level			
Less than $15,000	1(Reference)		
$15,000 to less than $25,000	0.90	0.77	1.05
$25,000 to less than $35,000	0.77*	0.65	0.92
$35,000 to less than $45,000	0.64*	0.54	0.77
$50,000 or more	0.55*	0.47	0.65
BMI (kg/m^2)			
Underweight (< 18.5)	1.64*	1.21	2.24
Normal weight (18.5-25)	1(Reference)		
Overweight (25-30)	0.87*	0.78	0.98
Obese (≥30)	1.13*	1.01	1.26
Smoking status			
Current (daily)	1.26*	1.07	1.49
Current (some days)	1.32*	1.07	1.63
Former smoker	1.23*	1.13	1.34
Never smoked	1(Reference)		
Comorbidities (no. of diseases)			
0	1(Reference)		
1	2.43*	1.82	3.24
2	3.15*	2.46	4.04
≥3	6.45*	5.11	8.14

*$p < 0.05$

Table 4. 12

Between group comparison of meeting physical activity guideline with regards to physical health

Variables	Odds Ratio	95% Confidence Interval for Odds Ratio	
		Lower	*Upper*
PA Guidelines			
Meeting both vs. Meeting aerobic activity only	1.14	1.00	1.30
Meeting aerobic activity only vs. Meeting MSA only	0.40*	0.34	0.47
Meeting both vs. Meeting MSA only	0.45*	0.39	0.54

The model adjusted for race, education, employment status, income level, BMI, smoking status, and comorbidities.
*$p < 0.05$

4.2.3.3 Mental Health

The full logistic regression model was statistically significant, χ^2 (35) = 1084.46, $p < .001$, which suggests that the association between mental health and all covariates included in this model was statistically significant. The model explained about 11.7% (Nagelkerke R^2) of the variance in mental health. According to the classification table, 92.5% of cases were correctly classified with 100% for good mental health and 0.7% for poor mental health.

Table 4.13 presents the adjusted odds ratios and 95% CI for all predictors of mental health in older adults. Compared to persons meeting neither PA guideline, the odds of having poor mental health reduced by 47% in participants meeting both aerobic activity and MSA guidelines (OR= 0.53, 95% CI: 0.45-0.63), by 42% in respondents achieving aerobic activity guideline only (OR= 0.58, 95% CI: 0.50-0.67), and by 21% among those meeting MSA guideline only (OR= 0.79, 95% CI: 0.66-0.93), after adjusting for all social-demographic and behavior factors. Table 4.14 shows the results of additional comparison between different PA categories. The odds of having poor mental health between participants who met both guidelines and those meeting aerobic activity guideline only were not statistically different. However, in comparison to respondents meeting MSA guideline only, there were significantly decreased odds of reporting poor mental health in individuals meeting both aerobic activity and MSA guidelines

(OR= 0.68, 95% CI: 0.55-0.83), and those meeting aerobic activity guideline only (OR= 0.74, 95% CI: 0.61-0.89).

The odds of having poor mental health decreased significantly with greater age. Older men had 18% lower odds of reporting poor mental health (OR= 0.82, 95% CI: 0.72-0.94) than women. Non-Hispanic blacks had 33% lower odds of having poor mental health (OR= 0.67, 95% CI: 0.56-0.81) than non-Hispanic whites. The odds of reporting poor mental health were 1.28 times greater in respondents who were never married (OR= 1.28, 95% CI: 1.01-1.63), and 24% higher in older adults who were separated /divorced/widowed (OR= 1.24, 95% CI: 1.07-1.43), than those married/unmarried couple. Compared to employed participants, there were significantly higher odds of reporting poor mental health in respondents who were unemployed (OR = 3.16, 95% CI: 2.05-4.85), homemaker (OR= 1.51, 95% CI: 1.11-2.05), retired (OR= 1.62, 95% CI: 1.37-1.91), and unable to work (OR= 3.95, 95% CI: 3.12-5.01). Having higher income levels was significantly associated with lower odds of having poor mental health. Older adults who were underweight had an 87% higher odds of reporting poor mental health (OR= 1.87, 95% CI: 1.19-2.94) than those with normal weight. Current smokers had higher odds of reporting poor mental health than those who never smoked. The odds of reporting poor mental health increased by 43% for heavy drinkers (OR= 1.43, 95% CI: 1.12-1.83). With increased number of comorbidities, a trend of higher odds of having poor mental health was identified, and those with having 3 or more comorbidities had the highest odds (OR= 5.67, 95% CI: 3.99-8.05).

Table 4. 13

Adjusted binominal logistic regression for poor mental health

Variables	Odds Ratio	95% Confidence Interval for Odds Ratio	
		Lower	*Upper*
PA Guidelines			
Meeting both	0.53*	0.45	0.63
Meeting aerobic activity only	0.58*	0.50	0.67
Meeting MSA only	0.79*	0.66	0.93
Meeting neither	1(Reference)		
Age			
65-69	1(Reference)		
70-74	0.82*	0.71	0.95
75-79	0.68*	0.58	0.80
≥80	0.53*	0.44	0.63
Sex			
Male	0.82*	0.72	0.94
Female	1(Reference)		
Race			
White, non-Hispanic	1(Reference)		
Black, non-Hispanic	0.67*	0.56	0.81
Other race, non-Hispanic	1.01	0.70	1.44
Multiracial, non-Hispanic	0.78	0.50	1.22
Hispanic	1.08	0.84	1.38
Education			
Did not graduate high school	1(Reference)		
Graduated high school	1.02	0.82	1.26
Attended college/technical	1.19	0.96	1.46
Graduated college	0.91	0.73	1.15
Marital status			
Married/unmarried couple	1(Reference)		
Never married	1.28*	1.01	1.63
Separated /Divorced/Widowed	1.24*	1.07	1.43
Employment status			
Employed	1(Reference)		
Unemployed	3.16*	2.05	4.85
Homemaker	1.51*	1.11	2.05
Student	0.52	0.13	2.09
Retired	1.62*	1.37	1.91
Unable to work	3.95*	3.12	5.01
Income level			
Less than $15,000	1(Reference)		
$15,000 to less than $25,000	0.94	0.76	1.16
$25,000 to less than $35,000	0.74*	0.59	0.94
$35,000 to less than $45,000	0.71*	0.56	0.91
$50,000 or more	0.61*	0.48	0.79
BMI (kg/m^2)			
Underweight (< 18.5)	1.87*	1.19	2.94
Normal weight (18.5-25)	1(Reference)		
Overweight (25-30)	0.90	0.78	1.04

Table 4. 13 (cont'd)

Obese (≥30)	0.94	0.82	1.08
Smoking status			
Current (daily)	1.36*	1.11	1.67
Current (some days)	1.32*	1.03	1.69
Former smoker	1.09	0.95	1.24
Never smoked	1(Reference)		
Heavy drinker			
No	1(Reference)		
Yes	1.43*	1.12	1.83
Comorbidities (no. of diseases)			
0	1(Reference)		
1	2.01*	1.35	3.00
2	2.81*	1.89	4.18
≥3	5.67*	3.99	8.05

*$p < 0.05$

Table 4. 14

Between group comparison of meeting physical activity guideline with regards to mental health

Variables	**Odds Ratio**	**95% Confidence Interval for Odds Ratio**	
		Lower	***Upper***
PA Guidelines			
Meeting both vs. Meeting aerobic activity only	0.92	0.77	1.09
Meeting aerobic activity only vs. Meeting MSA only	0.74*	0.61	0.89
Meeting both vs. Meeting MSA only	0.68*	0.55	0.83

The model adjusted for age, sex, race/ethnicity, education, marital status, employment status, income level, BMI, smoking status, heavy drinker, and comorbidities.
*$p < 0.05$

4.2.3.4 Activity Limitation

The logistic regression model was statistically significant, χ^2 (35) = 1726.17, $p < .001$, suggesting that the relationship between activity limitation and predictors included in this model was statistically significant. The model explained about 18.1% (Nagelkerke R^2) of the variance in activity limitation. The classification table indicated that 90.8% of cases were correctly classified with 99.4% for infrequent activity limitation days and 7.8% for frequent activity limitation days.

Table 4.15 shows the model based adjusted odds ratios and 95% CI for independent variables of activity limitation in older adults. Compared to respondents who met neither guideline, the odds of having frequent activity limitation days reduced by 60% in participants achieving both guidelines (OR= 0.40, 95% CI: 0.35-0.46), and by 63% among those meeting aerobic activity guideline only (OR= 0.37, 95% CI: 0.32-0.43), after controlling for all social-demographic and behavior factors. Nevertheless, no significant difference in odds of reporting frequent activity limitation days was found in individuals meeting MSA only and those meeting neither guideline. Table 4.16 provides additional comparison between different PA categories. The odds of having frequent activity limitation days were not significant when comparing participants meeting both guidelines to those meeting aerobic activity guideline only. Relative to persons meeting MSA guideline only, the odds of having frequent activity limitation days decreased by 66% in participants meeting aerobic activity guideline only (OR= 0.34, 95% CI: 0.29-0.41), and by 63% among people who met both guidelines (OR= 0.37, 95% CI: 0.31-0.44).

The odds of having frequent activity limitation days reduced by 12% in older adults aged 70-74 years (OR= 0.88, 95% CI: 0.78-0.99), and by 20% in participants aged 80 years and above (OR= 0.80, 95% CI: 0.69-0.94), compared to those who were within age group of 65-69. There was no significant sex difference in reporting frequent activity limitation days. Non-Hispanic Blacks had 38% lower odds of having frequent activity limitation days (OR= 0.62, 95% CI: 0.52-0.75) than non-Hispanic whites. Relative to employed participants, the odds of having frequent activity limitation days were significantly higher in older people who were unemployed (OR= 3.36, 95% CI= 2.33-4.84), homemaker (OR= 2.09, 95% CI= 1.51-2.91), retired (OR= 2.59, 95% CI= 2.13-3.15), and unable to work (OR= 9.83, 95% CI= 7.70-12.56). Respondents who were within the highest two income levels had significantly decreased odds of reporting

frequent activity limitation days than those whose annual income was less than $15,000. Overweight older persons had 16% lower odds of having frequent activity limitation days (OR= 0.84, 95% CI= 0.73-0.96) than those who had normal weight. By contrast, the odds of reporting frequent activity limitation days were significantly greater in elder adults who were underweight (OR= 2.26, 95% CI= 1.53-3.34) in comparison to normal weight people. In general, smokers had higher odds of having frequent activity limitation days than those who never smoked. Similar to other components of HRQoL, there was a trend of greater odds of having frequent activity limitation days with increased comorbidities. Compared to participants without comorbidities, the odds of having frequent activity limitation days were significantly higher in those with one comorbidity (OR= 2.46, 95% CI: 1.71-3.56), two comorbidities (OR= 2.87, 95% CI: 2.03-4.05), and 3 and more comorbidities (OR= 6.72, 95% CI: 4.89-9.24).

Table 4. 15

Adjusted binominal logistic regression for activity limitation

Variables	Odds Ratio	95% Confidence Interval for Odds Ratio	
		Lower	*Upper*
PA Guidelines			
Meeting both	0.40*	0.35	0.46
Meeting aerobic activity only	0.37*	0.32	0.43
Meeting MSA only	1.09	0.94	1.25
Meeting neither	1(Reference)		
Age			
65-69	1(Reference)		
70-74	0.88*	0.78	0.99
75-79	0.91	0.79	1.05
≥80	0.80*	0.69	0.94
Sex			
Male	1.08	0.97	1.20
Female	1(Reference)		
Race			
White, non-Hispanic	1(Reference)		
Black, non-Hispanic	0.62*	0.52	0.75
Other race, non-Hispanic	0.90	0.66	1.24
Multiracial, non-Hispanic	1.15	0.79	1.67
Hispanic	0.90	0.73	1.10
Education			
Did not graduate high school	1(Reference)		

Table 4. 15 (cont'd)

Graduated high school	0.86	0.72	1.03
Attended college/technical	1.13	0.94	1.35
Graduated college	0.98	0.80	1.19
Marital status			
Married/unmarried couple	1(Reference)		
Never married	0.94	0.72	1.21
Separated /Divorced/Widowed	0.99	0.88	1.11
Employment status			
Employed	1(Reference)		
Unemployed	3.36*	2.33	4.84
Homemaker	2.09*	1.51	2.91
Student	2.64	0.54	13.05
Retired	2.59*	2.13	3.15
Unable to work	9.83*	7.70	12.56
Income level			
Less than $15,000	1(Reference)		
$15,000 to less than $25,000	0.99	0.83	1.18
$25,000 to less than $35,000	0.82	0.68	1.00
$35,000 to less than $45,000	0.72*	0.59	0.88
$50,000 or more	0.59*	0.48	0.72
BMI (kg/m^2)			
Underweight (< 18.5)	2.26*	1.53	3.34
Normal weight (18.5-25)	1(Reference)		
Overweight (25-30)	0.84*	0.73	0.96
Obese (≥30)	1.10	0.96	1.26
Smoking status			
Current (daily)	1.23	1.00	1.51
Current (some days)	1.58*	1.23	2.03
Former smoker	1.27*	1.14	1.41
Never smoked	1(Reference)		
Heavy drinker			
No	1(Reference)		
Yes	0.91	0.68	1.21
Comorbidities (no. of diseases)			
0	1(Reference)		
1	2.46*	1.71	3.56
2	2.87*	2.03	4.05
≥3	6.72*	4.89	9.24

*$p < 0.05$

Table 4. 16

Between group comparison of meeting physical activity guideline with regards to activity limitation

Variables	**Odds Ratio**	**95% Confidence Interval for Odds Ratio**	
		Lower	***Upper***

Table 4. 16 (cont'd)

PA Guidelines			
Meeting both vs. Meeting aerobic activity only	1.09	0.92	1.29
Meeting aerobic activity only vs. Meeting MSA only	0.34*	0.29	0.41
Meeting both vs. Meeting MSA only	0.37*	0.31	0.44

The model adjusted for age, sex, race/ethnicity, education, marital status, employment status, income level, BMI, smoking status, heavy drinker, and comorbidities.
*$p < 0.05$

4.2.4 Moderated logistic regression

4.2.4.1 General health

After adding the sex× PA interaction variable into the model, the overall model remained significant, χ^2 (38) = 3195.71, $p < .001$. When compared to the model with all covariates, the new model (i.e., moderated model) was not significantly different from the old model, χ^2 = 3196.77 - 3195.71= 1.06, df = 3, $p = .79$. There was no change in the Nagelkerke R^2. According to the classification table, the overall correct classification rate was 80% with 94.9% for good and 29.8% for poor general health.

The sex× PA interaction term was not statistically significant, $p = .108$, indicating that sex did not moderate the relationship between PA and general health. Table 4.17 presents the moderation results for all levels.

Table 4. 17

Odds ratio and 95% confidence intervals of interaction between sex and PA for general health

Interaction term	**Odds Ratio**	**95% Confidence Interval for Odds Ratio**	
		Lower	***Upper***
PA × female			
Meeting both × male	1.09	0.88	1.36
Meeting aerobic activity only × male	1.10	0.90	1.33
Meeting MSA only × male	0.80	0.62	1.03

The model adjusted for age, sex, race/ethnicity, education, marital status, employment status, income level, BMI, smoking status, heavy drinker, and comorbidities.

4.2.4.2 Physical health

When the interaction term sex× PA was entered into the model, the new model was significant, χ^2 (32) = 3195.71, $p < .001$. Compared to the model with significant covariates only, the moderated model did not significantly improve the old model, χ^2 = 1750.09- 1740.98= 9.11, df = 4, p = .058. The new model explained about 16.6% (Nagelkerke R^2) of the variance in physical health. The classification table showed that 84.7% of cases were correctly classified, with 98.8% of the good physical health and 9.4% of the poor physical health correctly predicted.

The sex× PA interaction term was not significant, p = .534, which indicated that sex was not a moderator in the relationship between PA and physical health. Table 4.18 provides the moderation results for all levels.

Table 4. 18

Odds ratio and 95% confidence intervals of interaction between sex and PA for physical health

Interaction term	Odds Ratio	95% Confidence Interval for Odds Ratio	
		Lower	*Upper*
PA × female			
Meeting both × male	0.87	0.69	1.10
Meeting aerobic activity only × male	0.88	0.72	1.09
Meeting MSA only × male	0.91	0.69	1.20

The model adjusted for sex, race/ethnicity, education, employment status, income level, BMI, smoking status, and comorbidities.

4.2.4.3 Mental health

After the sex× PA interaction term was added to the model, the overall model remained significant, χ^2 (38) = 1080.98, $p < .001$. A test of the moderated model with the old model (i.e., model with all covariates) was not significant, χ^2 = 1084.46- 1080.98= 3.48, df = 3, p = .32. The Nagelkerke R^2 increased slightly to .118, indicating that the moderated model explained about 11.8% of the variance in mental health. Based on the classification table, the overall correct

classification rate was 92.5% with 100% for good mental health and 0.6% for poor mental health.

The sex× PA interaction term was not significant, $p = .113$, which indicated that sex did not moderate the relationship between PA and mental health. Table 4.19 presents the moderation results for all levels.

Table 4. 19

Odds ratio and 95% confidence intervals of interaction between sex and PA for mental health

Interaction term	Odds Ratio	95% Confidence Interval for Odds Ratio	
		Lower	*Upper*
PA × female			
Meeting both × male	0.92	0.65	1.29
Meeting aerobic activity only × male	0.75	0.56	0.99
Meeting MSA only × male	1.13	0.78	1.63

The model adjusted for age, sex, race/ethnicity, education, marital status, employment status, income level, BMI, smoking status, heavy drinker, and comorbidities.

4.2.4.4 Activity limitation

When the sex× PA interaction term was entered into the model, the new model remained significant, χ^2 (38) = 1728.38, $p < .001$. Compared to the model with all covaries, the moderated model was not significantly different, $\chi^2 = 1728.38 - 1726.17 = 2.21$, df = 3, $p = .53$. The Nagelkerke R^2 stayed same. The classification table showed that 90.8% of cases were correctly classified with 99.4% for infrequent activity limitation days and 7.8% for frequent activity limitation days.

The sex× PA interaction term was not statistically significant, $p = .963$, suggesting that sex did not moderate the relationship between PA and activity limitation. Table 4.20 provides the moderation results for all levels.

Table 4. 20

Odds ratio and 95% confidence intervals of interaction between sex and PA for general activity limitation

Interaction term	Odds Ratio	95% Confidence Interval for Odds Ratio	
		Lower	*Upper*
PA × female			
Meeting both × male	0.96	0.73	1.27
Meeting aerobic activity only × male	0.94	0.71	1.24
Meeting MSA only × male	1.02	0.76	1.37

The model adjusted for age, sex, race/ethnicity, education, marital status, employment status, income level, BMI, smoking status, heavy drinker, and comorbidities.

CHAPTER V: DISCUSSION

The purpose of this study was to 1) examine the associations between meeting PA guidelines and HRQoL among older adults, and 2) investigate if sex moderates the relationships between meeting PA guidelines and HRQoL. Results from the current study partially supported the first hypothesis. The key finding is that older adults meeting both aerobic activity and MSA or aerobic activity guidelines only had lower odds of having poor HRQoL than those who met MSA guideline only or met neither guideline. This indicates that meeting aerobic activity guideline is more important than meeting MSA guideline for the elderly in terms of HRQoL. Contrary to the second hypothesis, sex did not significantly moderate the relationships between meeting PA guidelines and any component of HRQoL in this study. The following discussion focuses on results of (1) meeting both PA guidelines and HRQoL, (2) meeting either aerobic activity or MSA guideline and HRQoL, (3) sex as a potential moderator, and (4) sociodemographic, biological, PA and behavioral factors and HRQoL.

5.1 Meeting both PA guidelines and HRQoL

Data from this study demonstrated that older adults who met both aerobic activity and MSA guidelines had lower odds of reporting poor HRQoL (e.g., general health, physical health, mental health, activity limitation) than those who met MSA guideline only or met neither guideline. It is worth noting that there are limited comparative data from which to draw parallels with findings from the current study. Only one similar study was identified that focused on investigating the association between meeting both PA guidelines and HRQoL, but that study was conducted in the general adult population. That study, which was a cross-sectional analysis of data from 441,456 respondents from the 2015 BRFSS revealed that adults meeting both guidelines reported significantly fewer days of poor mental health compared to those meeting

MSA only or meeting neither guideline (Fluetsch et al., 2019). This is consistent with findings from the current study. However, contrary to the current study's results showing no significant differences in the association of meeting both PA guidelines and meeting aerobic activity guideline only with any component of HRQoL in older adults, the previous study observed that participants who met both guidelines had significantly fewer days of poor mental health compared to those who met aerobic activity guideline only (Fluetsch et al., 2019). The inconsistent results might be explained by the different study population as participants in the current study were older adults aged 65 years and above whereas respondents in Fluetsch et al. (2019) were general adults aged 18 years and older.

The study's effect sizes (OR= 0.40-0.53) on the relationships of HRQoL with meeting both PA guidelines vs. meeting neither are small (Chen et al., 2010). The odds ratio of having poor general health, physical health, mental health, and activity limitation were not significantly lower for older adults who met both guidelines compared to those meeting aerobic activity guideline only, suggesting that aerobic activity contributes to the most benefits of improving the four components of HRQoL. Meeting MSA guideline only, however, almost doubled the odds of having poor general health, physical health, mental health, and activity limitation, compared to meeting both guidelines. Although these results are surprising considering the general perceived benefits of MSA to health, they lend further support to the benefits of participating in aerobic activity among older adults.

In summary, older persons meeting both aerobic activity and MSA guidelines had lower odds of poor HRQoL compared to those meeting MSA only or meeting neither. However, the effect sizes are small. The benefits of meeting both guidelines on HRQoL were mainly from aerobic activity.

5.2 Meeting either aerobic activity or MSA guideline and HRQoL

5.2.1 Meeting aerobic activity guideline only vs. meeting neither

This study showed that older adults meeting aerobic activity guideline only had significantly lower odds of poor HRQoL than those meeting neither PA guideline, which is in accordance with previous studies. For example, Vallance et al. (2012) surveyed 387 older men and found that meeting aerobic PA recommendation was associated with higher HRQoL scores. Likewise, based on data from 5,311 adults aged 60 years and above who participated in the National Health and Nutrition Examination Survey between 2007 and 2014, Xu et al. (2018) found that respondents who met and exceeded aerobic PA guideline had better general health and less physical unhealthy and activity limitation days. Similarly, with 357,665 participants from the 2009 BRFSS, Brown et al. (2014) reported that older adults aged 65 years or older who engaged in any amount of aerobic PA had reduced odds of poor HRQoL compared to inactive persons. In 5,359 US adults who participated in the National Health and Nutrition Examination Survey 2003-2006, Kim and his colleagues (2017) described that meeting aerobic PA guideline was associated with decreased risk of poor HRQoL and its components, particularly general health, physical health, and activity limitation. Additionally, an earlier study among 175,850 adults from general population concluded that recommended levels of aerobic PA were associated with better overall HRQoL and perceived health status (Brown et al., 2003). Likewise, data from 5,654 French adults suggested that participants meeting public health recommendation for moderate and vigorous aerobic PA had better HRQoL than those who did not meet the recommended PA (Vuillemin et al., 2005). Finally, a longitudinal study in a cohort of 1,097 community-dwelling older adults aged 62 years and older showed that meeting recommended aerobic PA was associated with better physical functioning, social functioning and emotional

role (Balboa-Castillo et al., 2011). The positive relationship between meeting aerobic activity guideline and HRQoL among older adults in the current study is in line with findings from previous cross-sectional studies.

The positive relationship between aerobic PA and HRQoL has also been reinforced in intervention studies. A 12-month randomized controlled trial among 179 older adults with a mean age of 66.43 years found that participants in the walking group reported an increase in mental health component of HRQoL compared to those in the control group (Awick et al., 2015). Consistently, Wanderley et al. (2012) conducted a randomized controlled trial for eight months among 75 community-dwelling older adults, and noted that the general health, mental health, and physical component summary domain were significantly improved in the aerobic training group compared to the waiting list control group.

The positive association between aerobic PA and HRQoL has also been confirmed in adults with chronic conditions. For example, a cross-sectional study among 33,071 US adults aged 45 years and older with physician-diagnosed arthritis reported that individuals who did not adhere to the aerobic guideline reported more unhealthy days for both physical and mental domains, compared with those who did (Austin et al., 2012). Additionally, evaluating the effects of a moderate-intensity aerobic exercise program on the cognitive function and HRQoL of elderly Chinese with mild cognitive impairment, data from a single-blinded randomized controlled trial with 120 older individuals revealed that the intervention group had a significantly greater improvement in HRQoL scores than the control group (Song & Yu, 2019).

Aerobic activity benefits HRQoL of older adults in a variety of ways. Older people meeting recommended aerobic PA were found to report higher physical function scores (Morey et al., 2008). Furthermore, more than 70% of the U.S. adults aged 65 years and older have high

blood pressure, which is associated with higher risk of stroke, coronary heart disease, peripheral arterial disease, kidney disease, and many other adverse outcomes (Mozaffarian et al., 2015). A meta-analysis of 23 studies found that controlled aerobic exercise training reduces resting blood pressure in previously sedentary older adults (Huang et al., 2013). Aerobic activity is also associated with a reduced risk of cognitive decline among older adults (Lee et a., 2015). Moreover, a systematic review and meta-analysis of 11 randomized controlled trials showed that aerobic activity significantly reduced several inflammatory markers in middle-aged and older adults, which is closely related to the initiation and progression of a broad range of diseases (Zheng et al., 2019). Additionally, Drogos et al. (2019) noted that aerobic exercise increase cortisol awakening response, which was associated with greater reductions in perceived stress. Aerobic activity improves older adults' HRQoL by lowering risk for chronic diseases, improving cognitive function and promoting mental health.

The effect sizes (OR= 0.37-0.58) on the relationships of HRQoL with meeting aerobic activity only vs. meeting neither are small (Chen et al., 2010). This is consistent with Brown and his colleagues' (2003) findings that also reported small effect sizes (OR= 0.36-0.48) of meeting aerobic PA guideline on physical and mental health component of HRQoL in older adults. Nevertheless, achieving the aerobic PA guideline appeared to have a medium effect size (OR= 0.24) on the activity limitation domain of HRQoL in the elderly (Brown et al., 2003). Moreover, another study investigating the relationship between aerobic PA and HRQoL among adults with and without limitations revealed small effect size (0.41-0.47) on the relationship between meeting aerobic activity guideline and physical/mental component of HRQoL in older adults aged 65 years and above (Brown et al., 2014). The small effect sizes of aerobic activity on HRQoL might be explained by short amount of time that participants engaged in regular exercise

since the BRFSS only assessed aerobic activity during the past month. It may also be attributed to the cross-sectional design of the study. Excluding aerobic PA less than 10 minutes per episode in BRFSS may account for small effect sizes of aerobic activity since short bouts of aerobic PA are beneficial.

Overall, results from prior studies including intervention research and the current study support a beneficial effect of participating in aerobic activity on improving HRQoL in older adults. However, the overall effects were small for four domains of HRQoL, which is consistent with most of the prior research. Given the above findings, future efforts should focus on promoting aerobic activity to improve HRQoL among older adults.

5.2.2 Meeting MSA guideline only vs. meeting neither

The current study contributes to PA and HRQoL literature by providing additional findings that meeting MSA only was associated with better general and mental health domains of HRQoL compared to meeting neither PA guideline, but not physical health or activity limitation components. These results are somewhat consistent with prior studies. With 441,456 adults, Fluetsch et al. (2019) found that respondents who met MSA only were less likely to report poor mental health than those meeting neither guideline. In a systematic review and meta-analysis with 16 randomized controlled trails, Hart and Buck (2018) concluded that resistance training was effective in improving all domains of HRQoL in older adults. Consistent with these findings, data from a single-blind randomized controlled trial in 119 participants aged 65 years and above showed that only the mental health component was significantly improved for the strength training group compared with control group after 12 weeks (Kimura et al., 2010). The benefits of MSA on general and mental health might be attributed to improvements in muscle strength,

which plays a critical role in the pathogenesis of frailty, maintaining physical function, and contributing to numerous disease processes (Peterson et al., 2010).

Contrary to the current study's results, several studies have pointed out that resistance training was effective in improving physical health domain of HRQoL. An intervention study in 49 men aged 60-81 years showed that role physical, general health, and physical component summary scores increased significantly after a 12-week strength training intervention, suggesting systematic strengthening training being an effective intervention for improving HRQoL in elderly men (Haraldstad et al., 2017). Similarly, a randomized controlled trial was conducted to evaluate the effects of eight-week resistance training with elements of stretching on improving HRQoL in 38 postmenopausal older women (Socha et al., 2016). It was found that the resistance training intervention increased HRQoL among older women in the dimensions of both physical function and mental dimension (Socha et al., 2016). Furthermore, Wanderley et al. (2012) compared the effects resistance training on HRQoL and observed that the physical component summary increased significantly in the resistance training group compared to the waiting list group. The incongruent findings from the current study and previous studies might be caused by the different amount of MSA participants engaged in with a possibility of lower amount of MSA in this study and higher levels in prior studies. However, the insignificant relationship between MSA and physical health domain of HRQoL in this study is supported by research evidence on the association between meeting MSA guideline and mortality, given the fact that HRQoL predicts mortality (Benyamini, 2011). Investigating the association between adherence to aerobic and MSA guideline and mortality risk among cancer survivors in the U.S., the observational study based on 1999-2009 National Health Interview Survey in 13,997 participants indicated that

engaging in recommended levels of MSA alone did not appear to reduce mortality in the study population (Tarasenko et al., 2018).

Although meeting MSA guideline only was associated with reduced odds of having poor general health and mental health, the effect sizes (OR= 0.87, 0.79) are very small (Chen et al., 2010). By contrast, Kimura et al. (2010) determined a medium effect ($\eta^2 = 0.065$) of 12-week strength training on mental health component of HRQoL. However, a systematic review of 16 randomized controlled trial studies showed that resistance training had small to medium effects (Effect size = 0.39-0.64) on mental domain of HRQoL and medium to large effects (Effect size = 0.50-0.81) on physical domain of HRQoL (Hart & Buck, 2018). Examining changes in HRQoL among 49 older men participating in 12-weeks systematic strength training, Haraldstad et al. (2017) noted that the strength training had a medium effect (Effect size= 0.54) on general health and a small effect (Effect size = 0.32) on physical component summary of HRQoL. The different effect sizes might be attributed to different study design with cross-sectional design for the current study and randomized-controlled trial for prior studies. The very small effect sizes of meeting MSA guideline on HRQoL in this study may be explained by how MSA was measured as it only assessed frequency without information on intensity and muscle groups involved, which may have overestimated older adults meeting MSA guideline. Another reason may be older adults do not have enough knowledge on MSA. Compared to aerobic activity guideline, MSA was included in PA guidelines more recent. It is possible that older individuals do not know how to engage in MSA appropriately. They may have low self-efficacy towards MSA or they might be concerned with possible injuries in participating in MSA. Although meeting MSA guideline does not discuss time, it is possible that total time MSA participation matters. The health benefits can be very different for a person who participates in MSA twice per week with

10 mins each time compared to another individual who engages in MSA with the same frequency but 60 mins each time.

To sum up, older individuals who met MSA guideline only had lower odds of poor general and mental health compared to those who did not meet any PA guideline. To date, there are limited cross-sectional studies in literature examining the relationship between meeting MSA guideline only and HRQoL. Intervention studies provided mixed evidence on MSA and HRQoL: some studies showed that resistance training improved all components of HRQoL whereas others found that resistance training only had influence on certain domains of HRQoL. Given these inconsistent results, more research with longitudinal study design is needed to clarify the beneficial effects of MSA on older adults' HRQoL.

5.2.3 Meeting aerobic activity guideline only vs. meeting MSA guideline only

Relative to participants meeting MSA guideline only, those meeting aerobic activity guideline only reported significantly reduced odds of having all four components of poor HRQoL. These results are consistent with those from a prior study among 441,456 respondents from the 2015 BRFSS showing that meeting aerobic activity only appeared to be more related to HRQoL than MSA (Fluetsch et al., 2019). In particular, those who only met aerobic activity guideline reported 0.85 fewer days of poor mental health per month compared to the participants who only met the MSA guideline (Fluetsch et al., 2019). Similar findings were reported in several intervention studies. For instance, in a randomized controlled trail, 179 low-active, older adults were randomly assigned to either a 12-month aerobic walking group or a strengthening and flexibility group (Awick et al., 2015). The walking group demonstrated an increase in mental health component of HRQoL, whereas the strengthening and flexibility group declined significantly with no changes in physical domain of HRQoL, which suggested that aerobic

activity appeared to benefit more than the strengthening and flexibility condition (Awick et al., 2015). In addition, another trial in 204 adults aged 37-77 years old noted that HRQoL (i.e., general health, mental health, and role physical) improved only in the endurance training group (Sillanpaa et al., 2012). The finding that meeting aerobic activity guideline appeared to be more beneficial than meeting MSA guideline is in line with previous studies.

As HRQoL predicts mortality (Brown et al., 2015), research on PA and mortality may also provide additional evidence on the relationship between MSA and HRQoL. Analyzing the 1999-2002 National Health and Nutrition Examination Survey data of 2,773 adults, Dankel et al. (2016) determined that meeting aerobic activity guideline was more important than meeting MSA guideline for the prevention of premature all-cause mortality, although both were important. Likewise, in a longitudinal study using a large nationally representative sample of 479,856 US adults, Zhao et al. (2020) noted that meeting aerobic PA guideline tended to provide greater survival benefits than meeting MSA guideline. Previous PA and mortality studies further confirmed the greater benefits of meeting aerobic activity guideline compared to MSA guideline.

Other studies, however, found no difference on the effects of aerobic PA vs. MSA on HRQoL. A meta-analysis of 11 randomized controlled trails on exercise and HRQoL in older community-dwelling adults suggested that there was no statistically significant difference on the relationships of strength training vs. aerobic training with HRQoL outcome (Kelley et al., 2009). Moreover, Wanderley et al. (2015) observed no differences between the aerobic and resistance training groups except for the mental health domain in a randomized controlled trial in 75 older adults. An explanation for the lack of difference between aerobic PA and MSA might be a smaller sample size in these studies, which limited the statistical power to detect meaningful differences.

In general, meeting aerobic activity guideline only was associated with lower odds of poor HRQoL than meeting MSA guideline only. To older adults, achieving aerobic activity guideline is more beneficial than achieving MSA guideline for improving HRQoL. Some previous cross-sectional and intervention studies indicated similar findings. Research on PA and mortality further supports the greater benefits of meeting aerobic activity guideline. A few other studies, however, did not observe significant different effects of aerobic PA vs. MSA on HRQoL in the elderly persons.

5.2.4 Summary

Older adults who met both PA guidelines or aerobic activity guideline only reported better HRQoL than people who met MSA guideline only or met neither guideline. The effect sizes were small, aligning with some previous studies. Literature has established the benefits of aerobic activity on improving HRQoL. The current study suggested that meeting aerobic activity guideline is more important for better HRQoL in older adults than meeting MSA guideline. Previous studies showed mixed findings on whether the effects of aerobic activity and MSA differed on HRQoL in older adults. Meeting MSA guideline only was associated with slightly lower odds of general and mental health of HRQoL. The effect sizes were very small, only half of the effect sizes of meeting aerobic activity only. This further emphasizes the critical role of meeting aerobic activity guideline to promote HRQoL in older individuals.

5.3 Sex as a potential moderator

Data from this study demonstrated that sex did not significantly moderate the relationship between PA and any component of HRQoL. Similar findings have been demonstrated by prior studies in the general adult population. In a population-based cross-sectional study, data from a total of 4,500 participants with a mean age of 53 showed no clear evidence of interactions

between sex and aerobic PA for physical as well as mental domain of HRQoL (Bertheussen et al., 2011). Likewise, investigating the combined association of aerobic PA and body mass index with HRQoL in 110,986 Canadian adults from the 2005 Canadian Community Health Survey, Herman et al. (2011) observed no apparent sex difference in the association of aerobic PA and HRQoL. Additionally, results from 357,665 respondents who participated in the 2009 BRFSS survey indicated that the association between aerobic PA and HRQoL was not significantly modified by sex (Brown et al., 2014). This study extends findings from the previous literature supporting the non-significant moderation effects of sex on the relationship between PA and HRQoL.

5.4 Sociodemographic, biological, PA, and behavioral factors and HRQoL

5.4.1 Sociodemographic factors, PA and HRQoL

Consistent with prior literature (Sun et al., 2013; Orfila et al., 2006), this study also found significant sex differences in PA and HRQoL. Specifically, more older men met both aerobic activity and MSA guidelines or met aerobic activity guideline only than women in this study, but no sex differences were found in meeting MSA guideline. Similarly, a prior study reported that a greater percentage of elderly men met aerobic activity guideline than elderly women (Keadle et al., 2016; Jefferis et al., 2014). Moreover, a systematic review including 53 studies found that older men were more likely than women to achieve regular PA, especially leisure-time PA (Sun et al., 2013). Sex differences were also noted in three components of HRQoL (i.e., physical health, mental health, and activity limitation) but not general health in current study. More females were in the advanced age group than males in this study, which may explain no sex difference in general health. Compared with older males, older females were more likely to have poor physical and mental health as well as activity limitation. In line with these findings, another

cross-sectional study with a sample of 33,071 US adults aged 45 years or older with arthritis determined that women reported more physically and mentally unhealthy days than men (Austin et al., 2012). Similar results were also found in a French study showing that men had higher scores than women in physical functioning, role physical, bodily pain, mental health, role emotional and vitality dimensions of HRQoL (Vuillemin et al., 2005). Therefore, further research efforts should consider the effects of sex when designing interventions to promote PA and HRQoL.

Regarding the relationship between age and HRQoL, this study found that adults aged 70 years and above had better mental health and those aged 70-74 years and 80 years and over had fewer activity limitation days, compared to the elderly aged 65-69 years. These findings indicate that some domains of HRQoL may improve with increased age, which conflicts with previous research. Analyzing age differences in HRQoL between the young old (aged 65-84 years) and the oldest old (aged 85 and over), a cross-sectional study with 257 healthy community-dwelling elderly people observed that the oldest old group had poorer HRQoL in both physical and mental dimensions of HRQoL than the younger old group (Etxeberria et al., 2019). However, other study also found better mental health in the older group (Hopman et al., 2009). Furthermore, Bierman (1999) concluded that older people are generally happier than younger old people, which may account for the better mental health among older age groups in the current study.

Compared to non-Hispanic whites, non-Hispanic blacks had poorer general health but better physical, mental health, and fewer activity limitation days. These results were somewhat supported by prior literature. For example, Skarupski et al. (2007) found that blacks had a significantly higher risk of having poor overall HRQoL than whites. Moreover, health research literature also demonstrated that African Americans had similar or better mental health outcomes

than whites (Mouzon, 2017). As expected, this study showed that Hispanics had poorer general health and physical health than non-Hispanic whites. Using data on 236,289 older adults from Medicare plans, Ng et al. (2014) pointed out that all racial/ethnic minority groups were significantly more likely than non-Hispanic whites to have adverse health and functional outcomes. Nevertheless, this is in contrast with findings from many previous studies indicating that Hispanics had better health than non-Hispanic whites (Markides & Coreil, 1986; Markides & Eschbach, 2005; Crimmins et al., 2005).

The positive relationship between socioeconomic status (SES) and health status has been well established (Bielderman et al., 2015; Adler, 2013). Compared to the elderly with education less than high school, those with education equal to or greater than high school had lower odds of having poor general health in this study. In line with this finding, Adams (2002) provided evidence that older people with higher levels of educational attainment had healthier outcomes. Current study also demonstrated a positive association between income and HRQoL. In particular, older persons with an annual income greater than $35,000 were less likely to have poor HRQoL across all four domains than those who earned annually less than $15,000. This clear and significant positive relationship between household income and HRQoL among older adults in the U.S. was also revealed in Huguet et al.'s study (2008). Further, Lubetkin et al. (2005) highlighted that both high levels of educational attainment and income were related to higher HRQoL in older people.

Relative to married/unmarried couple, older persons who were never married or separated/divorced/widowed had significantly greater odds of reporting poor mental health. This is not surprising since married/unmarried couples are more likely to receive emotional and social support from their spouses (Vanderhorst & McLaren, 2005). Previous research showed that older

adults who were involved in a partner relationship reported better well-being than those without a partner (Peters & Liefbroer, 1997). Although most respondents were retired in this study, employment status was found to be closely related to HRQoL. In comparison to individuals who were employed, those who were in other status (i.e., unemployed, homemaker, retired, unable to work) reported significantly greater odds of having poor HRQoL except for those being students. This is consistent with findings from other research showing that unemployed persons had significantly lower HRQoL than employed individuals (Lee et al., 2015). Moreover, the elderly who continued working after retirement reported greater life satisfaction than those who were fully retired or unemployed in Germany and Switzerland (Cho & Lee, 2014). Employment is an important factor of HRQoL because it not only provides income, but also a sense of engagement, role identification, and physical and mental stimulation (Blanc, 2004; Wanberg, 2012). In other words, continuous working in the older age may help foster improved HRQoL.

5.4.2 Biological, behavioral factors and HRQoL

In this study, older adults who were underweight reported poorer HRQoL across all four domains compared to those with normal weight. Obese participants were found to have poorer physical and mental health than those with normal weight. These findings are in accordance with the non-linear relationship between BMI and HRQoL reported in prior literature (Yan et al., 2004). Therefore, assisting older adults to maintain a healthy weight may help improve their overall HRQoL.

It is evident that older individuals with one or more chronic diseases had significantly higher odds of reporting poor HRQoL than those without comorbidity. The association appeared to be linear as the odds of having poor HRQoL were increasing with increased number of diseases. This is not surprising since multiple chronic conditions limited individuals' abilities to

participate in activities of daily living, leading to decreased HRQoL (Barile et al., 2013). Consistent with prior literature (Mody & Smith, 2006), this study found that current and former smokers had poorer HRQoL compared to respondents who never smoked. Moreover, both the current study and previous literature (Giesbrechet et al., 2011) showed that compared to older people who were not heavy drinkers, those heavy drinkers had poorer mental health. Thus, interventions focusing on successful management of chronic conditions and maintaining a healthy lifestyle habit can be promising in improving HRQoL in old population.

5.5 Strengths and limitations

This study has several strengths. First, to my knowledge, the current study is the first to investigate the relationships between meeting aerobic activity and MSA guidelines and HRQoL among older adults. Although MSA has been included in PA guidelines for over a decade, it is often omitted from public communication campaigns and national surveillance systems (Milton et al., 2018). Second, this study used a large nationally representative U.S. sample that improved statistical power of the study to determine the association between achieving PA guidelines and HRQoL in older people. Third, the comprehensive nature of the BRFSS data collection allowed for adjustment for several potential confounding factors (e.g., sociodemographic, lifestyle, chronic conditions). Fourth, participants in this study were from the general older adult population, thus increasing generalizability of the findings.

Despite these strengths, the study has several limitations. The cross-sectional design limits inference of causal relationship between PA and HRQoL. The possibility of reverse causality cannot be ruled out. Although PA can improve HRQoL, individuals with impaired HRQoL may be less able to participate in PA, such that higher HRQoL may be the cause rather than the consequence of higher levels of PA. Healthier persons may be more likely to engage in

PA, as factors leading to poor health or activity limitation may preclude PA participation (Cohen et al., 2016). A second limitation is the use of self-report measures of PA and HRQoL, which is subject to recall bias and social desirability. Some respondents may overestimate their PA to reflect the socially desirable nature of PA participation (Adams et al., 2005). Likewise, participants may underreport their physical, mental unhealthy days and activity limitation days to reveal good health, leading to underestimation of poor HRQoL. The HRQoL-4 only has four questions with each question assessing one domain of HRQoL. Using only one question to evaluate each component of HRQoL may lower the reliability and validity of results. Unlike other HRQoL scales, HRQoL-4 does not provide overall score, making it difficult to draw an overall conclusion about HRQoL or compare to the general population. A third limitation is that the question on MSA provided frequency only without information on intensity/duration/type. However, the PA guidelines for Americans recommend adults participate in MSA of moderate or high intensity and involve in all major muscle groups on two or more days per week (USDHHS,2018). The assessment of MSA did not specify intensity and involvement of major muscle groups, which could result in overestimation of the prevalence of meeting the MSA guideline. A fourth limitation is that PA and HRQoL were measured at a single point in this study. It remains unknown how adherence to PA guidelines or change in PA levels are related to HRQoL in older adults. A fifth limitation is that the 2019 BRFSS only included aerobic activity performed in episodes of at least 10 mins to count toward meeting the aerobic guideline. The second edition PA guidelines for Americans (USDHHS, 2018) removed the 10-minute minimum bout requirement. It is now known that PA for a little as 5 minutes has real health benefits. The 2019 BRFSS data may have underestimated respondents who met aerobic PA guideline. Additionally, significant differences in key demographic variables were observed between

missing cases and complete cases. Therefore, the complete case analysis in the current study may have given biased results (Hughes et al., 2019). Finally, although this study included 11 confounding variables, other unmeasured confounders might have influenced the association between PA and HRQoL such as diet quality, sleep quality and social support. Given the above limitations, the study's results need to be interpreted with caution.

5.6 Implications

The current study has multiple implications for practice and research. In practice, an important finding from this study is that older adults meeting both aerobic activity and MSA guidelines or aerobic activity guideline only had better HRQoL than those who met neither PA guideline or met MSA guideline only. Thus, PA, especially aerobic activity, needs to be integrated into health policies at all levels, including primary care, as a cost-effective approach to reduce the burden of poor health on older people and society in general (McPhee et al., 2016). Although the PA Guidelines for adults recommend both aerobic activity and MSA (USDHHS, 2018), a tailored PA guideline is needed for older people with an emphasis on aerobic activity. Moreover, it is necessary to increase the awareness of the importance of aerobic activity in this population, for example, health professionals can educate the elderly on the numerous benefits of aerobic activity. As PA is medicine for older adults (Taylor, 2013), exercise prescription should be available to a larger population, yet only 32% of clinicians provide exercise counseling or education to older individuals during an office visit (Barnes & Schoenborn, 2012). It is crucial for clinicians to have a better understanding of exercise prescription for older adults so that effective recommendations can be performed. Given the significant greater health benefits of aerobic activity shown in this study, aerobic activity can be prioritized over MSA for persons who are unwilling or unable to do both aerobic activity and MSA (Zhao et al., 2020). Since over

90% of the older adults had at least one comorbidity, they require preparticipation health screening due to potential risks occurred during PA participation (Riebe et al., 2015). Physicians may play a key role in motivating and advising older patients to begin and adhere to PA while considering their physical limitations and/or comorbidities.

There are also some implications for research. As previously mentioned, conclusion regarding causality cannot be made based on this study's results due to the cross-sectional nature. Therefore, well-designed longitudinal and/or intervention studies are needed in order to draw causal relationships between PA and HRQoL and better understand the mechanisms linking PA to HRQoL. While this study found that meeting aerobic activity guideline is more beneficial than MSA for older adults, the optimal level of aerobic activity for HRQoL in older adults is not clear. Further research is needed to determine the range of PA levels, including minimum and maximum thresholds, that have clinically meaningful effects on HRQoL in the elderly. The current study used self-reported measures, which might have resulted in recall bias. Future research using objective measures of PA such as accelerometers, which can provide a more accurate assessment of PA, is warranted to replicate the findings from the current study. Future research may consider using other HRQoL measures such as SF-36 and SF-12, to gain a deeper understanding on the relationships between PA and overall HRQoL in older adults. To reduce social desirability, future research may implement anonymous surveys. The social desirability hypothesis pointed out that some respondents may be reluctant to report their true attributes in the presence of an interviewer (Baker et al., 2010). Therefore, online surveys tend to result in lower social desirability compared to interviewer-administered survey. Future research may also use a social desirability scale to estimate the direction and magnitude of the social-desirability bias in survey items (). Additionally, researcher can apply the social-desirability correction factor

in the model to address the issue (Gittelman et al., 2015). Results from this study suggested that MSA has limited benefit on HRQoL in older adults, which conflicts with research evidence that supports the important role of MSA in improving HRQoL. This may be explained by how MSA was assessed as it was only based on frequency. In accordance with 2018 MSA guideline, future study should utilize MSA measures that includes information on intensity as well as whether it involves major muscle groups to investigate the relationship between meeting MSA guideline and HRQoL. Moreover, little is known about how changes in PA influence HRQoL. Research with measures at several time points should be carried out to determine how maintenance in meeting PA guidelines or change in status are associated with HRQoL. Additionally, further research may consider adjusting other confounders to gain deeper insights into the relationships between PA and HRQoL in the elderly.

5.7 Conclusion

This study demonstrated that meeting 2018 PA guidelines was associated with reduced odds of poor HRQoL in older adults. While achieving both aerobic activity and MSA guidelines is promising in improving HRQoL, aerobic activity contributed to the most benefits. The findings add to the literature on how meeting PA guidelines is related to HRQoL in the elderly individuals. The results highlight the importance of participating in PA, which can be used to inform future policy, programs, and research efforts to increase HRQoL in older people.

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