Physical Activity and Psychological Well-Being in Older Adults

by

Zhanjia Zhang

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Kinesiology)
in the University of Michigan
2020

Doctoral Committee:

Associate Professor Weiyun Chen, Chair
Associate Professor Natalie Colabianchi
Professor Ivo D. Dinov
Professor Bruno J. Giordani
Professor Dale Ulrich

Zhanjia Zhang

zzj@umich.edu

ORCID iD: 0000-0002-2678-0178

Dedication

This dissertation is dedicated to my wife, Wenxin Shen, and my parents, Xiufang Huang and Lingwei Zhang.

Acknowledgements

Pursuing the PhD degree has been the most challenging but fruitful experience that I have ever had in my life. I would not have been able to finish this dissertation and my PhD degree without the help and support from many incredible people.

I am grateful for the expertise and support provided by my dissertation committee members: Drs. Natalie Colabianchi, Ivo Dinov, Bruno Giordani, Dale Ulrich, and Weiyun Chen. I would like especially to thank my advisor, Dr. Weiyun Chen, for her constant support and guidance during my PhD study. I would like to thank my wonderful cohort-mates, Tiwaloluwa Ajibewa and Erica Twardzik, who always helped me when I needed it. I would also like to thank Tony Maino and Kristy Collins, without whom the intervention study and data collection would not have gone smoothly. I am thankful to the research team in my lab including Max Hernand, Alayna Margulis, Anna Osborne, Chloe Wendlandt, Haley Ottensoser, and Andy Murry, who helped the data collection for this dissertation.

I would like to express my deepest gratitude to each of my family members and especially my wife Wenxin Shen for their constant and unconditional support during the past four years.

Table of Contents

List of Tables

List of Figures

List of Appendices

Abstract

A growing body of research suggests that physical activity (PA) is positively associated with psychological well-being in various populations. However, previous studies have predominantly focused on the preventive or curative effect of PA on negative psychological disorders, such as depression and anxiety, while largely ignored the positive psychological well-being, which is commonly conceptualized by two distinct dimensions, i.e., hedonic well-being and eudaimonic well-being. Both hedonic well-being and eudaimonic well-being are predictive of various health outcomes in older adults. Therefore, there is a need for more research to explore the relationship between PA and psychological well-being, especially the positive aspects of psychological well-being, in the older population. This dissertation includes three distinct but related papers to extend our current knowledge on the relationship between PA and psychological well-being in older adults.

In the first study, I used the longitudinal data collected at three time points from the Health and Retirement Study (HRS) to examine the potential bidirectional relationship between PA and purpose in life, the latter of which is a key component of eudaimonic well-being, in a sample of 4591 older individuals. The cross-lagged panel analysis, adjusting for a range of sociodemographic and health covariates, did not support a bidirectional relationship between PA and purpose in life in older adults. While purpose in life was positively associated with future vigorous-intensity PA, moderate-intensity PA, and light-intensity PA, none of the PA variables predicted purpose in life in later time points.

The second study and the third study were based on a 12-week multicomponent intervention conducted in older adults living in retirement communities. A total of 58 participants were voluntarily assigned to the experimental group (n =40) or the comparison group (n=18). The intervention group attended three 45-min group exercise lessons per week and wore a Fitbit activity tracker during the weekdays for 12 weeks combined with weekly feedback and personalized activity goals. The second study only involved participants in the experimental group and examined the effectiveness and acceptability of the Fitbit activity tracker for promoting PA. Daily step counts measured by the Fitbit activity tracker indicated that participants had an average increase of 900 steps/day from baseline to the end of the intervention. Individual interviews and the Acceptance questionnaire suggested that the Fitbit activity tracker was an acceptable and useful tool for older adults to self-track their PA. The third study examined the intervention effects on life satisfaction, happiness, eudaimonic well-being, depressive symptoms. Linear mixed models revealed that participants in the experimental group significantly improved happiness compared to the comparison group after controlling for baseline age and self-rated health. However, there was no difference regarding the changes in life satisfaction, eudaimonic well-being, and depressive symptoms between the two groups.

Overall, this dissertation expands the current knowledge about the relationship between PA and psychological well-being in older adults. Combining the results from these studies suggests that the effect of PA on psychological well-being may differ by different components of psychological well-being. Future research should seek to explore the mechanisms linking the possible relationship between PA and psychological well-being, and develop more effective PA interventions to improve psychological well-being for the older population.

Chapter 1

Introduction

The older population in the US is growing rapidly. It is projected that the number of older adults aged 65 years and over will nearly double from 50 million now to 95 million by 2060, comprising 23% of the total population by that time (U.S. Census Bureau, 2018b). As aging is associated with declines in multiple domains of physical and cognitive health, the increasing number of the older population will also lead to a substantial increase of the individuals with high risks of various diseases, which will in turn increase health care costs. Psychological well-being is a crucial indicator of healthy aging. There is now considerable evidence suggesting that psychological well-being is associated with the morbidity of a range of diseases such as stroke and dementia, as well as all-cause mortality (Peitsch, Tyas, Menec, & John, 2016; Zaslavsky et al., 2014).

Although there is no consistent definition of psychological well-being, the concept of psychological well-being is commonly characterized by three dimensions including mental ill-being, hedonic well-being, and eudaimonic well-being (Keyes, 2002; McMahan & Estes, 2011). Mental ill-being concerns mental disorders and psychopathology and is the major focus of early health psychology studies. Hedonic well-being and eudaimonic well-being are two dimensions of positive psychological well-being and distinct from merely the absence of mental disorders (Ryan & Deci, 2001). Hedonic well-being focuses primarily on the subjective experience of happiness and life satisfaction, while eudaimonic well-being mainly concerns the positive

functioning, self-realization, meaning in life, and positive relations with others. There is compelling evidence that mental ill-being, hedonic well-being, and eudaimonic well-being are independently associated with various health outcomes in older adults (Steptoe, Deaton, & Stone, 2015). Therefore, identifying factors that can improve mental ill-being, hedonic well-being, and eudaimonic well-being in older adults may yield great public health benefits and inform better practice in future health promotion practice.

PA has been identified as a promising modifiable factor linked with psychological well-being in older adults. Accumulating evidence suggests that PA is favorably associated with mental ill-being, hedonic well-being, and eudaimonic well-being in older adults. For example, regular PA is associated with lower levels of depression (Paulo et al., 2016), greater life satisfaction (Ku, Fox, & Chen, 2016), and higher levels of purpose in life (Ju, 2017) in older adults. However, the relationship between PA and psychological well-being, and particularly the hedonic well-being and eudaimonic well-being, remains largely unexplored given the following limitations identified in previous research in this area.

Problem Statement

Although prior research suggests that PA might be a promising contributor to psychological well-being, the research on PA and psychological well-being, and especially the hedonic well-being and eudaimonic well-being, in older adults is still in its early stages. Reviewing the literature reveals several limitations in previous studies in this area. First, while the benefits of PA on mental ill-being seem relatively well established, far less research has addressed the relationship between PA and positive psychological well-being in older adults (Zhang & Chen, 2019a). Second, only a small number of studies have examined the relationship between PA and eudaimonic well-being in older adults. Although the results of these studies are

promising, most of them are cross-sectional studies and thus limit our understanding regarding the longitudinal and causal relationship between PA and eudaimonic well-being in the older population. Third, previous studies examining the effect of PA interventions on positive psychological well-being have mostly used single-form, group-based exercise programs such as aerobic exercises or resistance training. In contrast, the effect of multicomponent PA intervention on positive psychological well-being in older adults has been rarely studied. Therefore, more research is needed before the clear-cut understanding regarding the relationship between PA and positive psychological well-being in older adults can be reached.

Purpose of the Study

The purpose of this dissertation was to improve the understanding of the relationship between PA and psychological well-being in older adults by examining the relationship between PA and different dimensions of psychological well-being. This dissertation included three separate but related studies using both longitudinal and experimental approaches to address the research gaps outlined above. The first study aimed to examine the possible bidirectional relationship between PA (including vigorous-intensity PA, moderate-intensity PA, and light-intensity PA) and purpose in life, a key component of eudaimonic well-being, in an older adult sample using longitudinal data collected at three time points across eight years. The second study and the third study were based on a 12-week multicomponent PA intervention but with different focuses. The second study aimed to examine the effectiveness and acceptability of wearable activity trackers with self-regulatory techniques for promoting PA in older adults. The third study aimed to investigate the impact of a multicomponent PA intervention on life satisfaction, happiness, eudaimonic well-being, and depressive symptoms, reflecting different dimensions of

psychological well-being, in older adults. The results of these studies expanded our current knowledge on the relationship between PA and psychological well-being in older adults.

Hypotheses

Study 1: *Longitudinal Associations Between Physical Activity and Purpose in Life among Older Adults: A Cross-Lagged Panel Analysis*

Hypothesis 1a: On average, the levels of PA and purpose in life would both decrease over time in older adults.

Hypothesis 1b: Higher levels of vigorous-intensity PA, moderate-intensity PA, and light-intensity PA would be associated with higher levels of subsequent purpose in life.

Hypothesis 1c: Higher levels of purpose in life would predict higher levels of subsequent vigorous-intensity PA, moderate-intensity PA, and light-intensity PA.

Study 2: *Efficacy and Acceptability of Using Wearable Activity Trackers in Older Adults Living in Retirement Communities*

Hypothesis 2a: Using wearable activity trackers combined with self-regulatory techniques for 12 weeks would significantly improve the PA level in older adults.

Hypothesis 2b: Wearable activity trackers would be an acceptable tool for older adults to self-track their PA.

Study 3: *Impact of a 12-Week Multicomponent Physical Activity Intervention on Psychological Well-Being in Older Adults*

Hypothesis 3a: Individuals in the intervention group would significantly improve the life satisfaction compared with the comparison group.

Hypothesis 3b: Individuals in the intervention group would significantly improve the happiness compared with the comparison group.

Hypothesis 3c: Individuals in the intervention group would significantly improve the eudaimonic well-being compared with the comparison group.

Hypothesis 3d: Individuals in the intervention group would significantly reduce the depressive symptoms compared with the comparison group.

Chapter 2

Review of Literature

This chapter would review the literature related to the following topics: PA and aging, psychological well-being and aging, and findings from previous studies that have examined the relationship between PA and psychological well-being in the older population. The aim of this chapter was to familiarize readers outside this research area with the current knowledge about related topics and identify research gaps.

Physical Activity and Aging

The Aging Population and Health Concerns

The older adult population in the US, defined as those 65 years and older, is growing rapidly. According to 2018 Population Estimates, there are nearly 50 million people aged 65 years and over in the US, which comprises 15.61% of the total population (U.S. Census Bureau, 2018a). The Census Bureau projects that 20% and 23% of the US population will be older than 65 by 2030 and 2060, respectively (U.S. Census Bureau, 2018b). In addition, the "oldest old" population, referring to those who aged 85 years and over, is projected to increase from 6.3 million in 2016 to 9.1 million and 19 million in 2030 and 2060, respectively (U.S. Census Bureau, 2018b). The drastic change in the size and proportion of the older adults in the US is mainly due to the aging baby boomers and the increased life expectancy. The life expectancy at age 65 in the US has increased from 15.2 years in 1972 to 19.2 years in 2010 (Ortman, Velkoff, & Hogan, 2014).

Although older adults today live longer than previous generations, aging is associated with increased dysfunction and vulnerability (Butler, 1997). The age-related declines are pervasive in multiple dimensions of health, such as impaired cognitive functions, increased risk of falls, sensory impairment, and a decline in immune function (World Health Organization, 2015). The increasing proportion of older adults may lead to serious societal challenges due to the substantial increase in the number of individuals with impaired mental and physical health. For example, the proportion of older adults reporting at least one chronic disease increased from 86.9% in 1998 to 92.2 % in 2008, and the proportion of those who reported four or more chronic diseases increased from 11.7% in 1998 to 17.4% in 2008 (Hung, Ross, Boockvar, & Siu, 2011). The increased prevalence of chronic diseases in older adults leads to increased costs in health care and thus there is an urgent need for more research to guide efforts to promote the physical and mental health of older adults.

Health Benefits of PA for Older Adults

PA is broadly defined as "any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level" and involves detailed parameters such as intensity, type, and duration (World Health Organization, 2004). Although the term PA and exercise are often used interchangeably, exercise is a subcategory of PA that is "planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness" (Caspersen, Powell, & Christenson, 1985).

Participation in regular PA has been demonstrated to have substantial health benefits for older adults and these benefits continue to occur throughout their lives (Chodzko-Zajko et al., 2009). Findings from empirical studies and systematic reviews suggest that regular PA can help older adults maintain cardiovascular health (Huang, Gibson, Tran, & Osness, 2005), improve

sleep quality (Yang, Ho, Chen, & Chien, 2012), reduce the risk of falls (Sherrington, Tiedemann, Fairhall, Close, & Lord, 2011), and prevent type 2 diabetes (Umpierre et al., 2011), coronary heart disease (Batty, 2002), osteoporosis (Nikander et al., 2010), osteoarthritis (Roddy, Zhang, & Doherty, 2005), and many other chronic conditions. Regular PA helps older adults gain benefits in cognitive and brain functions, such as reducing the risk of dementia and improving the memory and executive function (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008; Colcombe & Kramer, 2003). Compared with sedentary older adults, physically active older adults have a lower rate of all-cause mortality in both men and women (Andersen, Schnohr, Schroll, & Hein, 2000).

In addition, regular PA is associated with higher levels of psychological well-being in older adults (McAuley & Rudolph, 1995). The empirical evidence regarding the relationship between PA and psychological well-being would be discussed in more detail later in a separate section because it is highly related to the study topic of this dissertation.

In summary, the health benefits of PA for older adults are comprehensive and well-documented. Although the biological aging process cannot be stopped by regular PA, regular PA can reverse or limit the development of age-related physiological and psychological deteriorations in older adults. Thus, PA might be a key lifestyle factor in differentiating individuals with or without successful aging (Chodzko-Zajko et al., 2009).

PA Guidelines for Older Adults

Despite the overwhelming evidence showing the health benefits of PA, a large number of US older adults do not participate in sufficient PA (Keadle, McKinnon, Graubard, & Troiano, 2016). The 2018 Physical Activity Guidelines for Americans recommends that older adults should engage 150 minutes of moderate-intensity, or 75 minutes of vigorous-intensity aerobic

physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity per week (US Department of Health and Human Services, 2018). The amount of time recommended in the Physical Activity Guidelines for Americans is similar to that in other health organizations, such as the World Health Organization (World Health Organization, 2010) and the American College of Sports Medicine (Haskell et al., 2007).

National Health Interview Survey (NHIS), National Health and Nutrition Examination Survey (NHANES), and Behavioral Risk Factor Surveillance System (BRFSS) are three major US surveillance systems for PA prevalence (Carlson, Densmore, Fulton, Yore, & Kohl, 2009). The proportion of older adults meeting the current PA recommendation was estimated to be 35.8% in NIHS, 27.3% in NHANES, and 44.3% in BRFSS, all by self-report measures (Keadle et al., 2016). Although the estimates vary across the surveillance systems, they all suggest that more than half of US older adults are insufficiently active. This estimate is even lower when PA is objectively measured. When PA is assessed by accelerometers, only 2.5% of older adults aged 60 years and above meet the PA recommendation (Troiano et al., 2008). In addition, older adults are less physically active than any other age group (Troiano et al., 2008).

Therefore, it is important to promote PA for older adults given the comprehensive health benefits of PA and the health risks of physical inactivity. According to the 2018 Physical Activity Guidelines, older adults who cannot meet the PA recommendation should be as physically active as their abilities and conditions allow and any amount of PA gain some health benefits (US Department of Health and Human Services, 2018). It is recommended that the PA programs for older should be multicomponent that include aerobic exercises, muscle strengthening exercises, flexibility exercises, and balance training because each type provides important health benefits (US Department of Health and Human Services, 2018).

Multicomponent PA interventions have been shown to be more effective than single-component PA interventions in improving functional ability and cognitive functions in older adults (Forte et al., 2013; Freiberger, Kemmler, Siegrist, & Sieber, 2016).

Interventions to Promote PA in Older Adults

Given the high prevalence of physical inactivity in the older population, effective ways to promote PA and to support long-term maintenance of PA for older adults are warranted. A number of interventions to promote PA for older adults have been developed during the past decades and the effectiveness of these interventions have been extensively examined. Most previous interventions to enhance PA in older adults are effective, although the effect sizes are generally small to moderate and limited to short-term (Van Der Bij, Laurant, & Wensing, 2002; Zubala et al., 2017).

Previous interventions to promote PA could be typically categorized as group-based interventions, in which participants engage in supervised group exercise programs (e.g., aerobic, strengthening, balance), and home-based interventions, in which participants are instructed to participate in PA at home (King, Rejeski, & Buchner, 1998). A review including 57 PA interventions indicated that home-based and group-based interventions are comparable regarding the short-term effectiveness in promoting PA (Van Der Bij et al., 2002). However, the long-term effectiveness in PA participation is stronger in home-based interventions than that in group-based interventions (Van Der Bij et al., 2002). Another review indicated that interventions combining home-based and group-based formats could be more effective than group-based intervention alone (Zubala et al., 2017). In addition, a substantial proportion of older adults prefer PA outside of a group-based format (Beauchamp, Carron, McCutcheon, & Harper, 2007).

Therefore, multi-modal interventions targeting both group-based and home-based PA might be more efficacious in promoting PA in older adults.

Regarding the mode of delivery, PA interventions could be delivered face-to-face or remotely (e.g., phone calls, text messaging, mail materials). A recent review compared 27 randomized controlled trials (RCTs) regarding the effect of health coaching on PA in older adults (Oliveira, Sherrington, Amorim, Dario, & Tiedemann, 2017). The findings from this review indicated that while both face-to-face and remotely delivered interventions were effective in promoting PA, intervention delivered through face-to-face sessions yielded a larger effect. In addition, another review indicated that whether PA interventions were delivered face-to-face or remotely, frequent contacts with participants were associated with stronger effectiveness (Conn, Valentine, & Cooper, 2002).

Previous evidence consistently suggests that interventions guided by behavior change theories and techniques are more effective in promoting PA than those are not. The most commonly used theory in previous interventions is the Social Cognitive Theory (Bandura, 1977), which emphasizes the role of self-regulation and self-efficacy in behavior change. A review examined 40 different behavior change techniques, as defined in the CAOL-RE taxonomy (Michie et al., 2011), in 19 PA interventions and found that self-regulatory techniques such as self-monitoring, setting behavioral goals, and providing feedback were most effective in promoting long-term PA in older adults (O'Brien et al., 2015).

Recently, the Social Ecological Model has gained increasing attention for its potential in guiding PA interventions. The Social Ecological Model posits that human behavior is influenced by the dynamic interaction between multiple individual and environmental factors (Sallis, Owen, & Fisher, 2015). Interventions guided by the Social Ecological Model have been effective in

promoting PA among different ages, including older adults (Heath et al., 2012). For example, Kerr et al. (2018) conducted a 12-month multilevel PA intervention among 307 older adults in eleven retirement communities. The intervention components of this study included individual counseling, self-monitoring with pedometers, group walks, group education sessions, and or local environment improvements. Older adults in the intervention group significantly improved light-intensity PA and moderate- to vigorous- intensity PA and had consistently higher levels of PA compared with the attention control group. Another study implemented a 6-month walking intervention in 563 older adults targeting both the individual level by providing an informational booklet and community level by providing peer-led walking groups in their own neighborhoods (Fisher & Li, 2004). The results of this study indicated that older adults in the intervention group significantly increased walking activities while no change was observed in the attention control group.

In summary, previous interventions are generally effective in promoting PA in the older population. It appears that multicomponent interventions combining both group-based and home-based formats, guided by behavior change theories, involving frequent contacts with participants, and targeting factors at multiple levels would be most effective in promoting PA in older adults.

Psychological Well-Being and Aging

Conceptualizing Psychological Well-Being

Psychological well-being is a key concept in positive psychology. Although there is currently no consensus in defining the psychological well-being, three approaches might help us to operationalize psychological well-being. Early studies in psychological well-being mainly focused on distress, depression, and other clinically symptoms (Ryan & Deci, 2001). In these studies, higher levels of psychological well-being are characterized as the absence or low levels

of mental ill-being. However, conceptualizing psychological well-being as the absence of mental ill-being largely ignores the positive aspects of psychological well-being. As defined by the World Health Organization (WHO), health is “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (World Health Organization, 2014). In their seminal paper on positive psychology, Seligman and Csikszentmihalyi (Seligman & Csikszentmihalyi, 2000) called for the need to shift the research focus in mental health from the negative psychological disorders to positive well-being.

In contrast to mental ill-being, hedonic well-being and eudaimonic well-being are two modern perspectives that emphasize the positive aspects of psychological well-being (Diener, 1984). Hedonic well-being focuses on maximizing one’s feeling of pleasure and satisfaction with life. With hedonic well-being, psychological well-being is usually defined as the high levels of positive affect, life satisfaction, and happiness, and low levels of negative affect (McDowell, 2010).

In contrast, the focus of eudaimonic well-being is on actualizing one’s human potentials and formulating positive human functioning (Ryff, 1989). A widely used framework of eudaimonic well-being consists of six psychological domains including purpose in life, autonomy, personal growth, environmental mastery, positive relations, and self-acceptance (Ryff, 1989). Purpose in life refers to the belief that one's life is purposeful and meaningful; autonomy refers to the sense of self-determination; personal growth refers to the sense of continued growth and development as a person; environmental mastery refers to the capacity to manage effectively one's life and surrounding world; positive relations refers to the possession of quality relations with others; and self-acceptance refers to the positive evaluations of oneself and one's past life (Ryff & Keyes, 1995). Eudaimonic well-being is also operationalized by other

scholars as flourishing (Keyes, 2002), as subjective vitality (Ryan & Frederick, 1997), and as meaningfulness (McGregor & Little, 1998).

Hedonic well-being and eudaimonic well-being are two distinct, though correlated, constructs, which has been demonstrated and supported by a large body of empirical and theoretical evidence (McMahan & Estes, 2011; Ryan & Deci, 2001). Although there are other existing classifications of psychological well-being, such as categorizing psychological well-being into deficit-oriented constructs and strength-based constructs (Tsang, Wong, & Lo, 2012), operationalizing psychological well-being by mental ill-being, hedonic well-being, and eudaimonic well-being is more theoretically grounded and reflects the shift of focus in well-being studies.

Psychological Well-Being and Successful Aging

Psychological well-being is a key indicator of successful aging. All of the three dimensions of psychological well-being are linked with many other health outcomes in older adults. Regarding mental ill-being, depression and anxiety disorders in older adults are associated with increased risk of morbidity, increased risk of suicide, cognitive decline, impaired physical and social functioning, and a number of medical illnesses (Blazer, 2003; Wolitzky‐Taylor, Castriotta, Lenze, Stanley, & Craske, 2010).

Regarding hedonic well-being, a systematic review of 35 studies found that positive affect and life satisfaction, independent of negative affect, were associated with reduced mortality (all-cause, cancer, cardiovascular) in both healthy older adults and older adults with chronic conditions (Chida & Steptoe, 2008). A prospective study showed that older adults with higher levels of life satisfaction were less likely to develop dementia in 5 years with the odds ratio being 0.7 (Peitsch et al., 2016).

Increasing evidence has documented that eudaimonic well-being, independent of hedonic well-being, is associated with better health outcomes in older adults. For example, a longitudinal study found that higher levels of purpose in life at baseline were associated with a reduced likelihood of stroke in four-year follow-up in older adults (E. S. Kim, Sun, Park, & Peterson, 2013). Boyle, Barnes, Buchman, and Bennett (2009) found that higher levels of purpose in life were linked with a reduced risk of all-cause mortality among community-dwelling older adults. Andrew, Fisk, and Rockwood (2012) found that personal growth, environmental mastery, positive relations, and self-acceptance were associated with frailty in older adults aged 70 and above. The positive association between eudaimonic well-being and health is also found in the oldest old population. Zaslavsky et al. (2014) found that higher levels of personal growth and purpose in life were associated with a lower risk of mortality in women aged 85 and older.

Although mental ill-being, hedonic well-being, and eudaimonic well-being are all linked with various health outcomes in older adults, the trajectories of these dimensions of psychological well-being may be different in aging. Contrary to the common perception, major depression is less prevalent in older adults than in any other age group (Fiske, Wetherell, & Gatz, 2009). Currently, the prevalence estimates are 2% to 3.6% for major depression and 6% to 8.1% for anxiety disorders in older adults (Byers, Yaffe, Covinsky, Friedman, & Bruce, 2010). Although the prevalence of depression is low in older adults, late-life depression is more chronic or prone to relapse and has a stronger association with suicidal behavior (Fiske et al., 2009).

Regarding hedonic well-being, the trajectory across the lifespan is typically characterized as a U-shaped curve. In other words, older adults are happier and more satisfied with life, as well as have higher levels of positive emotions and lower levels of negative emotions compared with middle-aged adults (Stone, Schwartz, Broderick, & Deaton, 2010). However, a worldwide

survey indicated that this U-shaped curve is only common in high-income countries (Steptoe et al., 2015). In Latin America and former Soviet Union countries, the level of hedonic well-being decreases progressively with age (Steptoe et al., 2015).

The trajectories of eudaimonic well-being in adulthood and later life are dependent on the domain of eudaimonic well-being. While autonomy and environmental mastery show incremental profiles with age, personal growth and purpose in life decline with advancing age, and positive relations with others and self-acceptance remain relatively stable or slightly increase with age (Ryff & Singer, 2008). Given the importance of the personal growth and purpose in life to health in later life, more efforts are needed to encourage older adults to develop a sense of purpose and self-realization.

The Relationship between PA and Psychological Well-Being in Older Adults

Researchers have long been interested in identifying the correlates of psychological well-being. As a modifiable health behavior, PA has been increasingly investigated in its relationship with psychological well-being. The following sections mainly describe the findings obtained from previous empirical studies to summarize what is known about the relationships between PA and mental ill-being, hedonic well-being, and eudaimonic well-being in older adults.

PA and Mental Ill-Being in Older Adults

Most previous studies on PA and psychological well-being in older adults have used PA as a preventive or curative approach for mental disorders, such as depression and anxiety. Both cross-sectional and longitudinal studies support the beneficial relationship between PA and mental ill-being. Using self-report measures, Paulo et al. (2016) found that older adults who did not meet the PA guidelines were 1.83 times more likely to present depressive symptoms than

older adults who did. For older adults with major depressive disorder, lower levels of PA were associated with more severe depressive symptoms (Moore et al., 1999).

The inverse association between PA and mental ill-being has also been demonstrated when PA was objectively measured. Using the data from the 2005–2006 NHANES, a study found that both light-intensity PA and moderate-to-vigorous PA, objectively assessed by accelerometers, were inversely associated with depression in older adults (Loprinzi, 2013). A review paper identified five prospective studies that examined the relationship between PA and depression in older adults and indicated that PA was preventive in the onset of depression in older adults (Mammen & Faulkner, 2013).

A great number of RCTs have provided stronger evidence in establishing the cause-and-effect relationship between PA and mental ill-being in older adults. These studies have demonstrated that various forms of PA have beneficial effects on depression in older adults, including aerobic exercises, resistance training, Tai Chi, and Yoga (Rhyner & Watts, 2016). For example, a 90-minute walking program once a week for 3 months significantly reduced depressive symptoms in community-dwelling older adults (Maki et al., 2012). Compared to non-exercise control, Lincoln, Shepherd, Johnson, and Castaneda-Sceppa (2011) found that a 16-week resistance training program with 45 min each time and three times per week significantly reduced depressive symptoms in older adults with diabetes.

A review article identified four RCTs that examined the impact of Tai Chi on depressive symptoms compared with waiting list controls in older adults (Chi, Jordan‐Marsh, Guo, Xie, & Bai, 2013). A meta-analysis of RCTs indicated a moderate effect of Tai Chi on reducing depressive symptoms in older adults (Chi et al., 2013). In addition, two studies (Blumenthal et al., 1999; Brenes et al., 2007) found that efficacy of aerobic exercises in treating major and

minor depression in older adults was equivalent to that of sertraline (a commonly used antidepressant medicine) and another study (Babyak et al., 2000) showed aerobic exercises were more effective in treating major depression compared to sertraline in older adults. Together, the findings from both observational and experimental studies strongly support that PA is an effective way of preventing and treating depression in older adults.

PA and Hedonic Well-Being in Older Adults

Previous studies on PA and hedonic well-being in older adults are mostly observational in nature. Using the data from the HRS, J. Kim, Chun, Heo, Lee, and Han (2016) found that higher levels of self-reported leisure-time PA were associated with higher levels of life satisfaction and positive affect in 1708 older adults with loneliness. In a recent cross-sectional study, Holahan, Holahan, Chen, and Li (2019) found that self-reported leisure-time PA was positively associated with high-arousal and low-arousal positive affect and negatively associated with high-arousal and low-arousal negative affect in older women. In a longitudinal study, older adults who had higher levels of leisure-time PA at baseline reported higher levels of life satisfaction at 8-year follow-up (Ku et al., 2016).

Parker, Strath, and Swartz (2008) examined the relationship between PA and hedonic well-being when the PA was measured by pedometers and accelerometers. While steps per day counted by pedometers were positively associated with life satisfaction and positive affect and inversely associated with negative affect, the accelerometer counts per day were only positively correlated with life satisfaction and inversely correlated with negative affect, and the minutes of moderate- and vigorous- intensity PA estimated by accelerometer were only negatively correlated with negative affect (Parker et al., 2008). Similarly, Fox, Stathi, McKenna, and Davis (2007) found that total daily energy expended estimated by accelerometer was positively

associated with life satisfaction in older adults, while the minutes of moderate-intensity PA, as well as the minutes of light-intensity PA, were not correlated with life satisfaction.

Two cross-sectional studies examined potential mechanisms underlying the relationship between PA and hedonic well-being. Barreto (2014) found that PA, indicated by metabolic equivalent (MET)-min/week, was associated with higher levels of happiness in older adults and this association was mediated by health status and social functioning. Another study found that PA was positively related to happiness and life satisfaction in older adults and the relationship was partially mediated by an individual's perceived health (Lera-López, Ollo-López, & Sánchez-Santos, 2017).

Several intervention studies have also examined the effects of exercises on hedonic well-being. Li et al. (2001) conducted a 6-month Tai Chi intervention among inactive older adults with 60 min each time and twice weekly and found that the intervention group experienced significant improvement in life satisfaction and positive affect and decrease in negative affect. Tse, Tang, Wan, and Vong (2014) found that an 8-week stretching and balancing exercise intervention with 60 min each time and once per week significantly improved happiness and life satisfaction in the intervention group but not in the usual care group among older adults living in nursing homes. A study compared the effect of a 6-month aerobic exercise intervention with that of a 6-month stretching exercise intervention on hedonic well-being among sedentary older adults, with 40 min each time and three times per week for both conditions (McAuley et al., 2000). The results of this study indicated that both aerobic exercises and stretching exercises lead to significantly increased happiness and life satisfaction after 6 months and there was no difference in the changes between two conditions.

Overall, the positive association between PA and hedonic well-being in older adults has empirical support, mostly from observational studies. There is a need for more future experimental studies to address the causality between the PA and hedonic well-being variables.

PA and Eudaimonic Well-Being in Older Adults

Relatively few studies have investigated the relationship between PA and eudaimonic well-being in older adults. In a cross-sectional study, J. Kim, Lee, Chun, Han, and Heo (2017) found that leisure-time PA was positively associated with purpose in life in a sample of 2414 older adults suffering from loneliness. Similarly, Ju (2017) found that PA was positively correlated with purpose in life and subjective vitality in 250 community-dwelling elderly women. In older adults diagnosed with osteoporosis, leisure-time PA was found to be positively associated with subjective vitality and this positive association was mediated by the psychological needs of competence, autonomy, and relatedness (Gunnell, Mack, Wilson, & Adachi, 2011). In a longitudinal study, Takkinen, Suutama, and Ruoppila (2001) found that older adults who had higher levels of PA at baseline reported higher levels of eudaimonic well-being at the 8-year follow-up. This study also suggested that the eudaimonic well-being mediated the positive relationship between PA and self-rated health and functioning.

Only one study has adopted the experimental design to examine the effect of exercises on eudaimonic well-being in older adults. Conradsson, Littbrand, Lindelöf, Gustafson, and Rosendahl (2010) conducted a 13-week exercise intervention in older adults living in residential care facilities. The experimental group in this study attended two 45-min high-intensity functional weight-bearing exercise classes while the control group received activities performed while sitting during the same time. However, the results of this study indicated that there was no

difference in the change of the feeling of satisfaction and acceptance of oneself and the environment between the intervention group and the control group.

In summary, research on the relationship between PA and eudaimonic well-being in older adults is still in its infancy. In particular, previous evidence has drawn heavily from cross-sectional studies. There is a need for both longitudinal and experimental studies to facilitate our understanding about the effect of PA on eudaimonic well-being in older adults.

Research Gaps Regarding the PA and Psychological Well-Being in Older Adults

In summary, emerging evidence has shown that regular PA is a promising factor contributing to higher levels of psychological well-being in older adults. However, there are several research gaps in the literature that limit our understanding and encourage further research into the relationship between PA and psychological well-being in older adults. One of the major limitations is that relatively few studies have examined the relationship between PA and positive psychological well-being as opposed to negative psychological symptoms. Particularly, the relationship between PA and eudaimonic well-being has been rarely studied in the older population. In addition, most of previous studies to date examining the relationship between PA and positive psychological well-being are based on observational data, highlighting the need for more experimental studies to clarify the effect of PA on different dimensions of psychological well-being and inform the development of effective interventions.

Chapter 3

Longitudinal Associations Between Physical Activity and Purpose in Life among Older Adults: A Cross-Lagged Panel Analysis

Abstract

Objective: The main purpose of the current study was to examine the possible bidirectional relationship between PA and purpose in life in an older adult sample, using longitudinal data collected at three time points across eight years.

Methods: Data were collected at three waves (2006, 2010, 2014) from the Health and Retirement Study, which provided repeated measures of PA and purpose in life. A total of 4591 participants (mean age = 74.32 years, 56.87% female) who had complete information of PA and purpose in life at the first wave were included in the current study. A series of cross-lagged models were tested separately for vigorous-intensity PA, moderate-intensity PA, and light-intensity PA to assess the bidirectional relationship between PA and purpose in life over time while adjusting for age, gender, education, race/ethnicity, marital status, self-rated health, and chronic conditions at baseline.

Results: For PA of each intensity, a model including significant autoregressive paths in which PA and purpose in life were positively associated with subsequent measurements of the same construct and paths from purpose in life to subsequent PA was most parsimonious and adequately fitted the data. In contrast, the paths between PA of each intensity and subsequent purpose in life did not reach significance.

Conclusion: The results did not support a reciprocal relationship between PA and purpose in life in older adults. While higher levels of purpose in life were associated with more frequent engagement in future vigorous-intensity PA, moderate-intensity PA, and light-intensity PA, none of the PA variables predicted subsequent purpose in life.

Early studies on health psychology in old adults have mainly focused on alleviating or treating mental disorders and dysfunction. This line of research is indeed important because mental disorders are linked with various health outcomes in older adults (Meeks, Vahia, Lavretsky, Kulkarni, & Jeste, 2011). However, health psychology research in older adults should be concerned not only with mental illness and dysfunction, but also supporting methods to enhance positive mental states. As defined by the World Health Organization (WHO), health is defined as "not merely the absence of disease or infirmity", but also "a state of complete physical, mental and social well-being" (World Health Organization, 2014). More recently, there is an increasing interest in positive psychology which has led to growing awareness of positive mental well-being, commonly conceptualized in terms of hedonic well-being and eudaimonic well-being and distinct from merely the absence of mental ill-being (Seligman & Csikszentmihalyi, 2000).

Hedonic well-being focuses on one's experience of happiness or pleasure through the satisfaction of preference (Diener, 1984), and eudaimonic well-being highlights the importance of purposeful or goal-directed activities in actualizing one's fullest potential (Ryan & Deci, 2001). Evidence has shown that both hedonic well-being and eudaimonic well-being are related to a number of health outcomes (Ryff & Boylan, 2016). However, compared with hedonic well-being, the current understanding on eudaimonic well-being is limited as it is less represented in the well-being literature, although evidence has shown eudaimonic well-being might be a more reliable and long-lasting indicator of individual or collective well-being (McMahan & Estes, 2011; Ryan, Huta, & Deci, 2008).

Among several facets of eudaimonic well-being, purpose in life is a construct that has received increasing interest due to its potential in predicting and promoting a range of health

outcomes. Purpose in life is generally defined as an individual's sense of meaning, purpose, and direction in his or her life and is central to one's well-being (Ryff, 2014; Steger, Frazier, Oishi, & Kaler, 2006). A small but increasing number of studies have shown that purpose in life is linked with a lower risk of stroke, Alzheimer's disease, myocardial infarction, and all-cause mortality (Boyle, Buchman, Barnes, & Bennett, 2010; E. S. Kim et al., 2013; Roepke, Jayawickreme, & Riffle, 2014). In addition, literature has documented favorable associations between purpose in life and an array of physiological markers such as interleukin-6 receptors, salivary cortisol, and high-density lipoproteins, all of which are further linked with a range of diseases (Friedman, Hayney, Love, Singer, & Ryff, 2007; Jacobs et al., 2011).

From a lifespan perspective, purpose in life may even be more important in the older population than other age groups because older adults on average have a lower level of purpose in life than young and middle-aged adults (Pinquart, 2002). As aging is associated with multiple physical and cognitive declines (Chen et al., 2015), identifying sources to maintain or increase the level of purpose in life may provide opportunities for novel interventions to promote health and protect or slow down the age-related declines in the older population.

PA has been identified as a promising source of purpose in life among many other factors. Evidence supporting the positive relationship between PA and purpose in life has been emerging across different age groups. For example, in a 6-month longitudinal investigation among female college students, Mack et al. (2012) found increases in health-enhancing PA were associated with increases in purpose in life. A randomized controlled trial showed that an 8-week Zumba intervention with 60 min each time and three times per week significantly improved purpose in life in adult women compared with the control group (Delextrat, Warner, Graham, &

Neupert, 2016). The positive association between PA and purpose in life was documented among older adults by two cross-sectional studies (Ju, 2017; J. Kim et al., 2017).

On the other hand, several studies have documented the reverse effect that purpose in life might also have an impact on PA. For example, cross-sectional studies demonstrated that higher levels of purpose in life predicted greater PA in middle-aged women (Holahan et al., 2011), cardiac patients (Holahan, Holahan, & Suzuki, 2008), and older adults (Ruuskanen & Ruoppila, 1995). The positive association between purpose in life and PA was also supported when PA was objectively measured by accelerometers among community-living adults (Hooker & Masters, 2016). In addition, a longitudinal study found that higher levels of purpose in life at baseline were associated with higher levels of self-report PA at 13-month follow-up among adolescents (Brassai, Piko, & Steger, 2015).

In summary, previous studies have either treated PA as a predictor of purpose in life and thus examined the PA-to-purpose relationship, or considered purpose in life as a predictor of PA and thus examined the purpose-to-PA relationship. There is both evidence for the effect of PA on purpose in life and the effect of purpose in life on PA, suggesting that PA and purpose in life might be reciprocally related. Although several papers (Homan & Boyatzis, 2010; Ju, 2017; Ruuskanen & Ruoppila, 1995) have discussed the possible bidirectional relationship between PA and purpose in life, no previous study has simultaneously tested the reciprocal relationship between them in a same sample. The majority of previous studies examining the association between PA and purpose in life were cross-sectional in nature and tested only one association of the direction, which precludes us from answering the question “which-came-first”. The possible bidirectional relationship and the extent to which the association might be stronger in one direction than the other could be examined using longitudinal data in which PA and purpose in

life are evaluated on two or more occasions. The existence of the bidirectional relationship between the two constructs would be inferred if PA predicts purpose in life over time, and in the meantime purpose in life predicts PA over time.

It is well-known that the ideal way to test causality is by conducting rigorously controlled experimental studies. However, while true experiments are relatively controllable when testing the PA-to-purpose relationship, it is somewhat unwieldy to manipulate the purpose in life. Consequently, cross-lagged panel designs are recommended with both variables being measured repeatedly over time (Kenny, 1975). The cross-lagged panel model allows us to estimate the directional influence between variables while simultaneously controlling for correlations within time-points and autoregressive effects (Kearney, 2017). The cross-lagged panel analysis has been previously used in exploring the reciprocal relationship between PA and other psychological constructs (Leonhardt et al., 2009). In addition, cross-lagged panel analysis can be performed using structural equation modeling framework, which enables us to control for the measurement error of latent variables (Kline, 2015).

Taken together, given the importance of both PA and purpose in life for the older population and the largely explored reciprocal relationship between these two constructs, the purpose of the current study was to investigate the association between PA and purpose in life in older adults using longitudinal data while taking into account the possibility of a bidirectional relationship. More specifically, the current study aimed to use a three-wave cross-lagged panel analysis in the structural equation modeling framework to examine whether PA would predict subsequent purpose in life in the older population or vice versa, or both. In addition, previous studies investigating the relationship between PA and purpose in life did not differentiate PA of different intensities. As PA intensity is an important parameter of PA, the current study aimed to

separately investigate the longitudinal relationship between vigorous-intensity PA, moderate-intensity PA, light-intensity PA, and purpose in life in older adults. Based on previous evidence, we hypothesized that: 1) on average, the levels of PA and purpose in life would both decrease over time; 2) higher levels of PA would be associated with higher levels of subsequent purpose in life; 3) higher levels of purpose in life at baseline would be associated with higher levels of subsequent PA.

Methods

Study Design and Participants

The current study used data collected from three waves (2006, 2010, 2014) of the Health and Retirement Study (HRS). The HRS, conducted by the Institute for Social Research at the University of Michigan, is an ongoing nationally representative longitudinal study of more than 37000 individuals aged 50 and over in the USA (Sonnega et al., 2014). The survey has been fielded every two years since its original data collection in 1992. The HRS has focused on a wide range of variables of health, cognition, and economics during the process of aging and retirement (Sonnega & Smith, 2015). In 2006, the HRS added the assessment of various psychosocial variables such as social support, loneliness, and purpose in life. The HRS has been widely used as a useful source in studying the changes in health associated with aging (Choi, McDonough, Kim, & Kim, 2018; Crosswell et al., 2018).

Since 2006, half of HRS participants were randomly chosen and assigned to an enhanced face-to-face interview with physical, biological, and psychosocial measures. The other half of the sample only completed the core interview in 2006 and received enhanced face-to-face interviews in 2008. The two half-samples alternatively received the enhanced face-to-face interviews and therefore the longitudinal information for the psychosocial variables (e.g., purpose in life) is

available every four years. Additional information about the design and procedures of the HRS has been published elsewhere (Sonnega et al., 2014). The current study used the data collected in 2006 (T1), 2010 (T2), and 2014 (T3) that contained the repeated assessment of PA, purpose in life in the same sample.

Participants who were 65 years or older and had complete measurement of PA and purpose in life at T1 were included in the current study. Data were available from 4591 participants at T1. Among them, 3687 participants were successfully reinterviewed at T2, and 2818 participants were successfully reinterviewed at T3.

Measures

Physical activity. PA was measured using three items assessing the frequency of PA involved in one's daily life including vigorous-intensity PA, moderate-intensity PA, and light-intensity PA. For example, the item for vigorous-intensity PA was "How often do you take part in sports or activities that are vigorous, such as running or jogging, swimming, cycling, aerobics or gym workout, tennis, or digging with a spade or shovel?" The response option was based on a 7-point scale ranging from 1 (hardly ever or never) to 7 (every day). Higher scores indicated higher levels of vigorous-intensity PA, moderate-intensity PA, and light-intensity PA, respectively. Evidence for validity indicated that these items were moderately correlated with objectively measured PA (Hamer, Lavoie, & Bacon, 2014).

Purpose in life. Purpose in life is measured using a seven-item subscale (Appendix A) adapted from the Ryff's Scales of Psychological Well-Being (Ryff, 1989). The original scale had 20 items for purpose in life but several shortened versions have been developed and tested ranging from three to fourteen items (Ryff, 2014). A sample item was "I enjoy making plans for the future and working to make them a reality." Respondents were asked to rate the extent to

which they endorse each item on a 6-point Likert scale from 1 (strongly disagree) to 6 (strongly agree). After reversely coding the negatively worded items, a composite score was calculated by summing all items with higher scores representing higher levels of purpose in life. Previous studies have documented the adequate validity and reliability for the use of the seven-item scale for purpose in life in older adults (Homan, 2016; Vella-Brodrick & Stanley, 2013). Cronbach's alpha for the current study were 0.72 at T1, 0.76 at T2, and 0.75 at T3, indicating good internal consistency.

Covariates. Several sociodemographic and health variables at T1 were included as covariates since evidence has shown they were potentially linked with purpose in life and PA.

Sociodemographic variables included self-reported age (in years), gender (male/female), race/ethnicity (White/Caucasian, Black/African American, and others), and marital status (married/not married), and educational level (no degree/high school diploma or GED/ college degree or higher).

Health-related variables included self-rated health and an index of chronic conditions. Self-rated health was assessed using a single-item question "would you say your health is excellent, very good, good, fair, or poor?" with a 5-point Likert scale ranging from 1 (poor) to 5 (excellent). The number of chronic conditions was assessed using 8 items asking participants if they have been diagnosed with 8 conditions, including (1) high blood pressure, (2) diabetes, (3) cancer or malignant tumor (excluding minor skin cancer), (4) lung disease, (5) heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems, (6) stroke, (7) emotional, nervous, or psychiatric problems, and (8) arthritis or rheumatism. An index ranging from 0 to 8 was created by summing all items with higher scores indicating the presence of more chronic conditions.

Data Analysis

Descriptive statistics for participant characteristics at baseline including sociodemographic and health variables were presented using means, standard deviations, or counts, as appropriate. The differences in baseline characteristics between individuals with and without missing data were examined using independent samples t tests or Chi-square tests. Means, standard deviations, and bivariate correlations for PA of different intensities and purpose in life at each wave were also presented. To examine the changes of PA and purpose in life over time, separate linear mixed models were conducted with vigorous-intensity PA, moderate-intensity PA, light-intensity PA, and purpose in life as the dependent variables and time as the independent variable while controlling for the baseline sociodemographic and health covariates. The descriptive statistics, independent samples t tests, Chi-square tests, and linear mixed models were performed using R version 3.5.

To estimate the reciprocal influences between PA and purpose in life among older adults, a series of cross-lagged structural equation models were performed. In the current study, purpose in life was conceived as a latent factor which has seven indicators (i.e., the seven items from the Scales of Psychological Well-Being). The univariate normality of each observed variable was examined by checking the skewness and kurtosis. The absolute value of skewness greater than 3 and/or the absolute value of kurtosis greater than 10 was considered as non-normal (Kline, 2015). For the non-normal observed variables, possible transformations (e.g., log transform, square transformation) would be applied.

For PA of each intensity, four models were tested to examine the bidirectional hypothesis between PA and purpose in life over time. Model 1 was considered as the baseline model in which only autoregressive paths are included (e.g., the path from PA at T1 to PA at T2, and the

path from PA at T2 to PA at T3). These autoregressive paths provided information about the stability of the variables with higher path coefficients indicating greater stability. Model 2 had the autoregressive paths and paths from PA to subsequent purpose in life. Model 3 had the autoregressive paths and paths from purpose in life to subsequent PA. Model 4 was a fully cross-lagged model which included autoregressive paths, paths from PA to subsequent purpose in life, and paths from purpose in life to subsequent PA. For all models, correlations between the error terms of PA and purpose in life were allowed to be freely estimated. In each model, covariates described previously were controlled for at T1.

All cross-lagged panel analyses were computed using Mplus version 8.1 (Muthén & Muthén, 2019). Parameters in each model were estimated using the full information maximum likelihood estimation method, which is an advanced method handling miss data and produces unbiased parameters on the basis of all available observed variables (Arbuckle, Marcoulides, & Schumacker, 1996). Model fit was evaluated using the model chi-square with its degrees of freedom and *p* value, Steiger–Lind Root Mean Square Error of Approximation (RMSEA), Bentler Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Standardized Root Mean Square Residual (SRMR). A good model fit would be indicated by non-significant chi-square, CFI $\geqslant$ .95, TLI $\geqslant$ .95, SRMR $\leqslant$ .05, and RMSEA $\leqslant$ .05 along with its 90% confidence interval $\leqslant$ .1 (Kline, 2015). An adequate model fit would be indicated by non-significant chi-square, CFI $\geqslant$ .90, TLI $\geqslant$ .90, SRMR $\leqslant$ .08, and RMSEA $\leqslant$ .08 (Brown, 2015). It should be noted that the significance level of model chi-square is highly sensitive in the case of a large sample size (Bollen, 1989). Therefore, the model chi-square would not be used as a decisive model fit index for a single model in the current study. Chi-square difference tests were used to compare the model fit between nested models (e.g., Model 1 and Model 2).

Results

Baseline Characteristics

Descriptive statistics of baseline characteristics for the overall sample were presented in Table 3.1. The mean age of participants at baseline was 74.32 ± 7.11 years. The majority of participants were female (56.87%), white/Caucasian (85.28%), and married (61.31%), and obtained a high school diploma or a college degree (77.19%). The mean score of self-rated health was 3.10, indicating a good level of self-rated health, while participants had an average of 2.37 chronic conditions.

Attrition Analyses

A total of 2761 participants had complete data at all three waves and 1830 participants had available data at either one or two waves. Compared to those without missing data, attrition analyses revealed that participants with missing data at follow-ups were older (77.17 vs. 72.43 years, $p < 0.001$), more likely to be male (47.4% vs. 40.3% , $p < 0.001$), not married (43.2% vs. 35.6% , $p < 0.001$), and not graduate from high school (28.1% vs. 19.2% , $p < 0.001$). In addition, participants with missing data had a greater number of chronic conditions (2.68 vs. 2.17, $p < 0.001$) and lowers levels of self-rated health (2.78 vs. 3.31, $p < 0.001$), vigorous-intensity PA (1.65 vs. 2.06, $p < 0.001$), moderate-intensity PA (2.93 vs. 3.51, $p < 0.001$), light-intensity PA (3.28 vs. 3.83, $p < 0.001$), and purpose in life (29.52 vs. 32.05, $p < 0.001$). There was no difference regarding the race/ethnicity between participants with and without missing data.

PA and Purpose in Life at Each Wave

Descriptive statistics of PA and purpose in life at each wave were shown in Table 3.2. Bivariate correlations (Table 3.3) indicated that PA of different intensities and purpose in life

within and between waves were all positively correlated (p's < 0.001). The correlations within each wave were greater than the correlations between waves. In addition, values of skewness and kurtosis indicated normality for vigorous-intensity PA, moderate-intensity PA, light-intensity PA, and purpose in life at each wave. Linear mixed models (Table 3.4) revealed a decreasing pattern of PA of each intensity and purpose in life over time after controlling for a range of covariates. Specifically, vigorous-intensity PA, moderate-intensity PA, light-intensity PA, and purpose in life on average decreased .02, .08, .10, and .18 points in the corresponding scale each year (p's < .001).

Cross-Lagged Panel Analyses Between PA and Purpose in Life

The results of model fit indices and Chi-square difference tests of the cross-lagged models for vigorous-intensity PA, moderate-intensity PA, and light-intensity PA were presented in Table 3.5-3.7. Findings were similar for PA of each intensity. Specifically, model 3 (i.e., purpose in life-to-PA model) was chosen as the final model for PA of each intensity. This was determined by comparing the model fit between different models and examining the significance of paths in each model. Model 3 showed an adequate-to-good fit to the data for vigorous-intensity PA (CFI = 0.950, TLI = 0.937, RMSEA = 0.025, SRMR = 0.035), moderate-intensity PA (CFI = 0.953, TLI = 0.940, RMSEA = 0.025, SRMR = 0.032), and light-intensity PA (CFI = 0.940, TLI = 0.923, RMSEA = 0.028, SRMR = 0.037). For PA of each intensity, the model fit of model 3 was significantly better than model 1 (baseline model) and was not significantly different from model 4 (full cross-lagged model). In addition, in model 4, the paths between PA of each intensity and subsequent purpose in life were all non-significant.

Standardized path coefficients of the final model for vigorous-intensity PA, moderate-intensity PA, and light-intensity PA were presented in Figure 3.1-3.3. As expected, both PA and

purpose in life were positively associated with subsequent measurements of the same construct. The standardized autoregressive coefficients for PA ranged from 0.283 to 0.365 from T1 to T2 and 0.287 to 0.342 from T2 to T3 (p's < 0.001). The standardized autoregressive coefficients for purpose in life ranged from 0.940 to 0.970 from T1 to T2 and 0.834 to 0.898 from T2 to T3 (p's < 0.001), indicating that purpose in life was rather stable over time.

Cross-lagged paths from purpose in life at T1 to PA at T2 (vigorous-intensity PA: β = 0.164, p < 0.001; moderate-intensity PA: β = 0.240, p < 0.001; light-intensity PA: β = 0.277, p < 0.001;) and from purpose in life at T2 to PA at T3 (vigorous-intensity PA: β = 0.079, p < 0.001; moderate-intensity PA: β = 0.194, p < 0.001; light-intensity PA: β = 0.205, p < 0.001;) were all positive and significant. In contrast, cross-lagged paths from PA at T1 to purpose in life at T2, as well as from PA at T2 to purpose in life at T3 were all non-significant for PA of each intensity. The results indicated that purpose in life positively predicted PA at later time points, but PA did not predict purpose in life at subsequent time points.

Additionally, we conducted a sensitivity analysis to confirm the final models by only including individuals with no missing data (n = 2761). Results indicated that the model fit and significance of path coefficients were not substantially changed for PA of each intensity.

Discussion

The current study examined the longitudinal relationships between PA of different intensities and purpose in life in older adults using data collected at three time points across eight years. As expected, we found that PA of different intensities and purpose in life decreased slowly over time in older adults. These findings support several previous studies which also demonstrated an age-related decline of PA and purpose life in later life (Milanović et al., 2013; Musich, Wang, Kraemer, Hawkins, & Wicker, 2018). The current study also revealed that the

strongest predictor of PA at subsequent waves was PA at previous waves, and the same was also found for purpose in life. This indicates a certain level of stability in PA and purpose in life over time and supports the control for the autoregressive effects in the models. The current study was the first study to investigate the bidirectionality between PA and purpose in life in older adults using a cross-lagged panel analysis. However, the reciprocal relationship between PA and purpose in life was not supported by the current study. While higher levels of purpose in life were associated with higher levels of subsequent vigorous-intensity PA, moderate-intensity PA, and light-intensity PA, none of the PA variables was associated with subsequent purpose in life. Comparing the strength of associations between purpose in life and PA of different intensities, it suggested that purpose in life had a stronger association with light-intensity PA than that with vigorous-intensity PA and moderate-intensity PA. Furthermore, it appeared the unidirectional prospective relationship between purpose in life and PA was long lasting since purpose in life at both T1 and T2 predicted future PA.

While some previous studies suggested PA was a predictor of purpose in life, none of the vigorous-intensity PA, moderate-intensity PA, and light-intensity PA predicted future purpose in life in the current study. The inconsistent findings might be explained by the difference in study designs. For example, a cross-sectional study involving 250 community-dwelling older adults with a mean age of 72.4 years found that PA frequency was significantly associated with purpose in life (Ju, 2017). A similar positive association between PA and purpose in life was also found in another cross-sectional study involving 2414 older adults with loneliness (J. Kim et al., 2017). Indeed, it might be true that PA had a cross-sectional relationship with purpose in life in older adults, as indicated by the significantly positive bivariate correlations between PA and purpose in life in the current study. However, when the longitudinal data was used and the autoregressive

effects were controlled in the current study, PA was no longer a predictor of future purpose in life. This suggested that the cross-sectional relationship observed might predominantly be caused by the influence of purpose of life on PA rather than the opposite. So far, there was only one randomized controlled trial examining the effect of exercises on purpose in life which involved adult women with a mean age of 27.3 years (Delextrat et al., 2016). This study found that an 8-week exercise intervention based on Zumba was effective in improving purpose in life (Delextrat et al., 2016). Therefore, the effect of PA on purpose in life might also differ by different age groups, which could be further explored in future studies.

The observed associations in the current study between purpose in life and subsequent PA were consistent with findings from previous research. For example, a cross-sectional study that purpose in life was a significant predictor of PA in older adults aged 65 to 84 years after controlling for self-rated health, depressive symptoms, and education (Ruuskanen & Ruoppila, 1995). Such association was also found in two other cross-sectional studies involving healthy older adults (Holahan & Suzuki, 2006) and older cardiac patients (Holahan et al., 2008). The current study extends prior knowledge by providing more definitive evidence of a longitudinal association between purpose in life and PA in older adults. The prospective association between purpose in life and PA was found in other two longitudinal studies involving adolescents (Brassai et al., 2015) and adults (Hooker & Masters, 2016), indicating that purpose in life might be a consistent predictor of PA across the lifespan.

Although the current study did not explore the mechanisms underlying the relationship between purpose in life and PA, some theories and previous studies may shed light on how purpose in life influences future PA. Ryff and Singer (1998) hypothesized that individuals with higher levels of purpose in life are more likely to pay attention to their health and thus engage in

positive health behaviors. Wisemann and Hannich (2011) confirmed this hypothesis demonstrating that purpose in life was associated with multiple health behaviors in older adults. Hooker and Masters (2016) speculated that individuals with a greater sense of purpose in life are more likely to be internally motivated and maintain PA. Researchers have proposed that purpose in life may influence PA by improving self-efficacy, as Rush and colleagues (2019) found that the positive relationship between purpose in life and PA in middle-aged adults was fully mediated by self-efficacy. Nevertheless, the mechanisms linking purpose in life to PA still remain largely unexplored and await further elucidation.

The findings from the current study have both theoretical and practical implications for health promotion in the older population. As the link between PA and better health is well-documented in older adults, efforts to encourage their pursuit of a meaningful life may result in health benefits through active engagement of PA. Several recent interventions using meaning-centered therapy (Breitbart et al., 2012) and cognitive behavioral therapy (Ruini & Fava, 2012) have shown to be promising in raising the sense of purpose in life. In addition, such purpose-in-life enhancement interventions could be incorporated into PA interventions to improve intervention outcomes.

Several limitations of the current study should be considered. First, the current study was limited by the self-reported measure of PA. Moreover, PA of each intensity was measured using a single item assessing the frequency, which did not reflect other parameters of PA, such as duration. Therefore, future assessment of PA in HRS may consider adding objective measures such as accelerometers or using more detailed self-reported questionnaires. Second, although the cross-lagged panel analysis provided useful information about prospective relationships between PA and purpose in life over time, it should be kept in mind that the conclusive causal relationship

between them could not be inferred due to the observational nature of the study. Third, the missing cases at T2 and T3 might cause potential bias of the findings, as the independent t tests revealed significant differences in several baseline characteristics between participants who had complete data and those who had incomplete data across the three waves. Nevertheless, we did not delete any cases and used the full information maximum likelihood estimation method to minimize the potential bias. The sensitivity analysis involving only individuals without missing data also did not change the results. Fourth, the consecutive waves of repeated measurement were spaced four years apart, which limits us to detect shorter-term variations in PA and purpose in life among older adults. Fifth, purpose in life is only one component of eudaimonic well-being, and thus the relationship between PA and purpose in life may not be generalizable to other components of eudaimonic well-being. Last, although a wide range of covariates were controlled for in the current study, some other variables that may potentially influence the results were not included such as cognitive function and pain, which could be addressed in future studies.

Despite these limitations, the current study has several considerable strengths. To our knowledge, the current study is the first study to assess the reciprocal relationship between PA and purpose in life, both of which have important health implications for the older population. The use of cross-lagged panel analysis allowed simultaneous investigation of each direction of the associations between PA and purpose in life while controlling their autoregressive effects. In addition, the longitudinal study design with three waves across 8 years enabled us to study changes in PA and purpose in life over a long period. A further strength was the large sample size of the HRS, which assured adequate statistical power to detect the associations between PA and purpose in life over time. Moreover, a wide range of covariates were included in the current

study to minimize potential confounding effects on the relationship between PA and purpose in life in older adults.

Conclusion

In conclusion, the findings of the current study suggested a non-reciprocal relationship between PA and purpose in life in older adults. Higher levels of purpose in life predict greater future engagement in vigorous-intensity PA, moderate-intensity PA, and light-intensity PA, but not vice versa. Future research is needed to replicate these findings using objective measures of PA and disentangle the mechanisms linking purpose in life to PA in older adults. Interventions to enhance the sense of purpose in life may improve older adults' health through its positive influence on PA.

Table 3.1 Characteristics of the overall sample at baseline

Variable	**Sample n = 4591**
Age (Mean ± SD)	74.32 ± 7.11
Gender	
Male	1980 (43.13%)
Female	2611 (56.87%)
Race	
White/Caucasian	3519 (85.28%)
Black/African American	550 (11.98%)
Others	129 (2.74%)
Marital status	
Married	2814 (61.31%)
Not married	1776 (38.69%)
Education	
No degree	1047 (22.81%)
High school diploma or GED	2546 (55.46%)
College degree or higher	998 (21.74%)
Self-rated health (Mean ± SD)	3.10 ± 1.07
Chronic conditions (Mean ± SD)	2.37 ± 1.39

Table 3.2 Descriptive statistics of PA and purpose in life at each wave

	T1 (n=4591)		T2 (n=3687)		T3 (n=2818)	
	Mean	SD	Mean	SD	Mean	SD
Vigorous-intensity PA	1.90	1.46	1.93	1.43	1.89	1.45
Moderate-intensity PA	3.28	1.76	2.91	1.69	2.82	1.74
Light-intensity PA	3.61	1.56	3.20	1.53	3.02	1.50
Purpose in life	31.05	6.60	31.66	6.73	30.64	6.70

Table 3.3 Bivariate correlations between PA and purpose in life at each wave*

	1	2	3	4	5	6	7	8	9	10	11	12
1. VPA-T1	-											
2. MPA-T1	.32	-										
3. LPA-T1	.17	.40	-									
4. PIL-T1	.19	.21	.19	-								
5. VPA-T2	.41	.25	.16	.15	-							
6. MPA-T2	.27	.36	.21	.19	.38	-						
7. LPA-T2	.18	.22	.33	.19	.24	.37	-					
8. PIL-T2	.18	.15	.14	.59	.18	.19	.21	-				
9. VPA-T3	.36	.21	.07	.13	.45	.28	.14	.13	-			
10. MPA-T3	.24	.29	.17	.20	.31	.39	.19	.19	.38	-		
11. LPA-T3	.18	.20	.25	.18	.23	.28	.42	.19	.25	.36	-	
12. PIL-T3	.16	.17	.13	.53	.17	.21	.19	.58	.18	.24	.23	-

* All the bivariate correlations were significant with p values < .001

Table 3.4 Summary of linear mixed models (coefficients and standard errors)

	Vigorous-intensity PA		Moderate-intensity PA		Light-intensity PA		Purpose in life	
	B	SE	B	SE	B	SE	B	SE
Year	-.02***	.00	-.08***	.00	-.10***	.00	-.18***	.02
Baseline age	-.02***	.00	-.02***	.00	-.04***	.00	-.15***	.01
Gender (female)	-.31***	.03	-.23***	.04	.47***	.04	.20	.17
Race (Black)	.07	.05	-.08	.06	-.23***	.05	1.90***	.26
Race (others)	.14	.10	.23	.12	-.10	.10	.28	.50
Education (high school)	.03	.04	.14**	.05	.09*	.04	1.36***	.21
Education (college)	.32***	.05	.36***	.06	.17**	.05	2.85***	.26
Marital Status (not married)	-.04	.04	-.02	.04	-.14***	.04	-.89***	.18
Self-rated health	.25***	.02	.35***	.02	.27***	.02	1.26***	.09
Chronic conditions	-.07***	.01	-.11***	.02	-.06***	.01	-.48***	.06

*: $p < .05$; **: $p < .01$; ***: $p < .001$

Table 3.5 Cross-lagged models for vigorous-intensity PA

	Chi-square	**CFI**	**TLI**	**RMSEA**	**SRMR**	**Chi-square difference**
Model 1: Baseline model	1475.8	.947	.934	.026 (.025, .028)	.040	
Model 2: PA to purpose in life	1470.6	.947	.933	.026 (.025, .028)	.040	M2 vs. M1: 5.2
Model 3: Purpose in life to PA	1401.2	.950	.937	.025 (.024, .027)	.035	M3 vs. M1: 74.6***
Model 4: Full cross-lagged	1396.9	.950	.937	.025 (.024, .027)	.035	M4 vs. M3: 4.2

*: $p < .05$; **: $p < .01$; ***: $p < .001$

Table 3.6 Cross-lagged models for moderate-intensity PA

	Chi-square	**CFI**	**TLI**	**RMSEA (90% CI)**	**SRMR**	**Chi-square difference**
Model 1: Baseline model	1523.7	.944	.929	.027 (.026, .028)	.044	
Model 2: PA to purpose in life	1516.1	.944	.929	.027 (.026, .028)	.044	M2 vs. M1: 7.6*
Model 3: Purpose in life to PA	1324.8	.953	.940	.025 (.023, .026)	.032	M3 vs. M1: 198.9***
Model 4: Full cross-lagged	1318.9	.953	.940	.025 (.023, .026)	.031	M4 vs. M3: 5.9

*: $p < .05$; **: $p < .01$; ***: $p < .001$

Table 3.7 Cross-lagged models for light-intensity PA

	Chi-square	**CFI**	**TLI**	**RMSEA (90% CI)**	**SRMR**	**Chi-square difference**
Model 1: Baseline model	1873.7	.928	.909	.031 (.029, .032)	.052	
Model 2: PA to purpose in life	1871.7	.928	.909	.031 (.029, .032)	.051	M2 vs. M1: 2.0
Model 3: Purpose in life to PA	1627.0	.940	.923	.028 (.027, .030)	.037	M3 vs. M1: 246.7***
Model 4: Full cross-lagged	1625.6	.939	.923	.028 (.027, .030)	.037	M4 vs. M3: 1.4

*: $p < .05$; **: $p < .01$; ***: $p < .001$

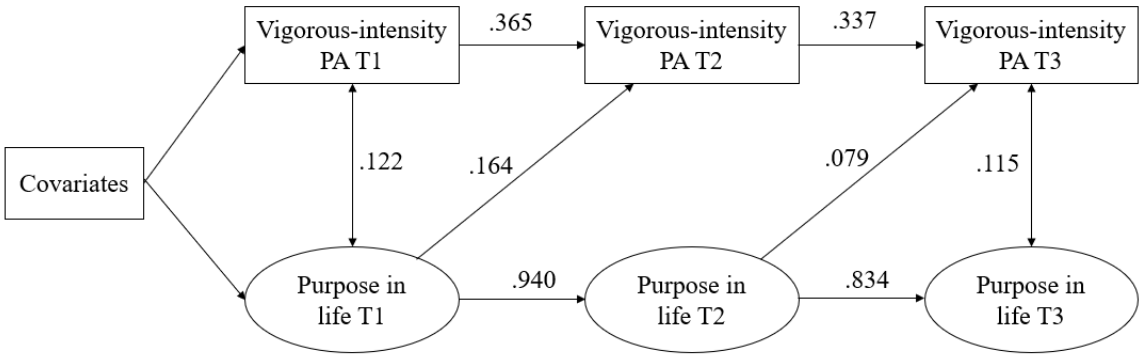

Figure 3.1 Standardized coefficients of the cross-lagged model between vigorous-intensity PA and purpose in life.

Note. Only significant paths are presented (p's < 0.05). Controlled covariates include age, gender, race/ethnicity, marital status, education, self-rated, and chronic condition at baseline.

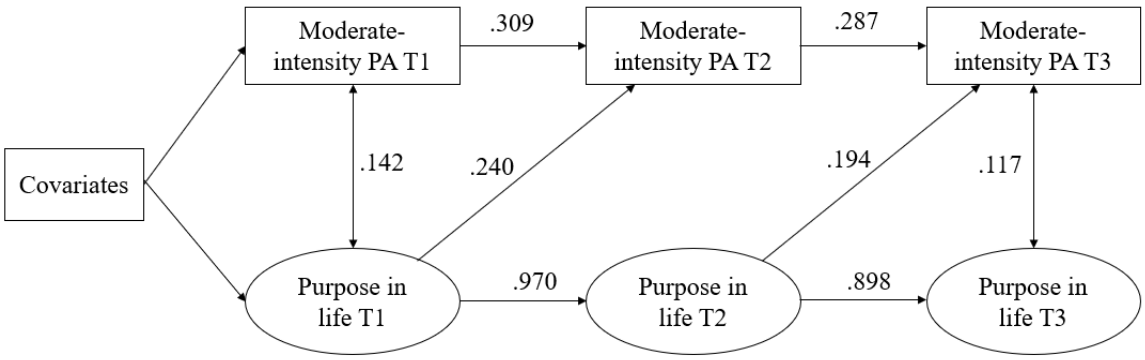

Figure 3.2 Standardized coefficients of the cross-lagged model between moderate-intensity PA and purpose in life.

Note. Only significant paths are presented (p's < 0.05). Controlled covariates include age, gender, race/ethnicity, marital status, education, self-rated, and chronic condition at baseline.

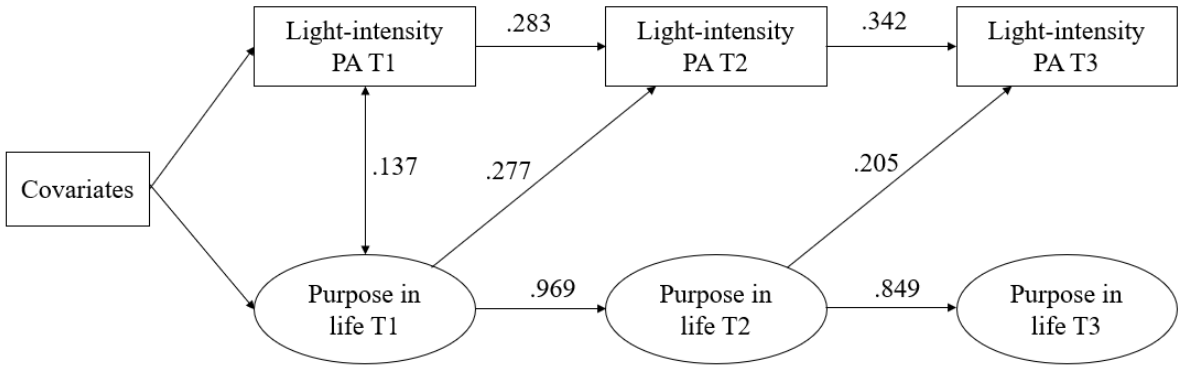

Figure 3.3 Standardized coefficients of the cross-lagged model between light-intensity PA and purpose in life.

Note. Only significant paths are presented (p's < 0.05). Controlled covariates include age, gender, race/ethnicity, marital status, education, self-rated, and chronic condition at baseline.

Chapter 4

Efficacy and Acceptability of Using Wearable Activity Trackers in Older Adults Living in Retirement Communities

Abstract

Objective: Wearable activity trackers hold the potential for enhancing health and fitness, but the use of wearable activity trackers has remained largely unexplored in older adults. The purpose of the current study was to examine the effectiveness and acceptability of wearable activity trackers for promoting PA in older adults living in retirement communities.

Methods: Forty older adult participants (mean age = 85.4 years; SD = 5.2) used a wearable activity tracker (Fitbit InspireHR) for 12 weeks. Participants were provided with personalized activity goals and weekly feedback of PA during the 12 weeks. The main outcomes were daily step counts collected at baseline and the end of the intervention via the wearable activity tracker, and participants' experiences of using the wearable activity tracker assessed after the 12-week intervention through an 8-item questionnaire and individual interviews.

Results: Participants wore the activity tracker on 97.5% of measured days and had an average increase of 900 steps/day ($t = 3.56$, $p < 0.001$, Cohen's d =0.3) from baseline to the end of the intervention. The Acceptance questionnaire revealed that the wearable activity tracker was acceptable, useful, and easy to use. Participants found that the wearable activity tracker helped improve self-awareness and motivation of PA but reported a few concerns regarding the comfort of wearing the activity tracker and the ease of reading visual feedback.

Conclusion: Wearable activity trackers lead to a small but significant increase of PA and are perceived as acceptable and useful in older adults. Given the rapidly growing older population, wearable activity trackers are promising tools that could be used in large-scale interventions to improve PA and health in older adults.

Regular PA is associated with various physical and mental health benefits in older adults, including lower risk of mortality, better cardiovascular health, improved sleep quality, and reduced risk of functional disability (Chodzko-Zajko et al., 2009). The 2018 Physical Activity Guidelines for Americans recommends that older adults participate in at least 150 minutes of moderate-intensity PA or 75 minutes of vigorous-intensity PA per week to obtain substantial health benefits (US Department of Health and Human Services, 2018). Despite the well-documented links between PA and health, only 27% of older adults aged 65 and older meet the PA guidelines according to the National Health and Nutrition Examination Survey (Centers for Disease Control and Prevention, 2012), and this number drops to 2.5% when PA is objectively assessed by accelerometers (Troiano et al., 2008). Therefore, effective interventions that aim to increase PA levels in the older population are warranted.

Among many types of PA, walking is identified as the favorite type of exercise among older adults (Stathokostas & Jones, 2016). Interventions targeting walking are most likely to be effective in changing PA behaviors in older adults (Niven & Markland, 2016). As a cost-effective type of exercise, it is estimated that 10% of the adult population participating in a regular walking program could save $5.6 billion in heart disease costs (Centers for Disease Control and Prevention, 2008). Therefore, effective interventions aiming at increasing the walking among older adults may translate into reduced health care costs.

Interventions designed to increase PA usually incorporate various behavior change techniques (Heath et al., 2012). A systematic review examined the effects of 26 behavior change techniques using a meta-regression and found that self-monitoring had the greatest individual effect in changing PA (Michie, Abraham, Whittington, McAteer, & Gupta, 2009). It was also found that interventions combining self-monitoring with at least one other technique of self-

regulation (e.g., goal setting, providing feedback) were more effective in promoting PA than other interventions (Michie et al., 2009). Self-monitoring is a key component of self-regulation based on the Social Cognitive Theory (Bandura, 1991). According to this theory, self-monitoring one's performance helps individuals set realistic goals and assess their progress toward these goals (Bandura, 1991). Self-monitoring one's PA also enhances one's self-efficacy for PA, which is a direct predictor of participation in PA (Ashford, Edmunds, & French, 2010).

Wearable activity trackers have been increasingly used as a self-monitoring tool in PA interventions and incorporate multiple behavior change techniques. A recent study examined the behavior change techniques implemented in 13 commercially available activity trackers and found that self-monitoring and feedback were the mostly incorporated techniques among these activity trackers (Lyons, Lewis, Mayrsohn, & Rowland, 2014). Wearable activity trackers monitor an array of PA indicators (e.g., step counts, distance walked, calories burned) and provide real-time feedback of these data for users. Unlike traditional hip-worn pedometers which require users to manually record daily step counts for long-term tracking, recent advances in technology allow wearable activity trackers to transmit and store data wirelessly through internet- or mobile- based applications (Lyons et al., 2014). Previous interventions using wearable activity trackers as a tool for promoting PA have shown promising results in various populations. For example, a randomized controlled trial conducted among overweight and obese adults showed that participants who wore a wearable activity tracker for six weeks increased daily step counts by 1266, while the attention control group showed no increase in daily step counts (Wang et al., 2015).

Interventions integrating the appropriate use of wearable activity trackers to promote PA in older adults has considerable public health importance for the aging society. First, as PA is

associated with various health outcomes and the older adults are more universally sedentary than any other age group (de Rezende, Rey-López, Matsudo, & do Carmo Luiz, 2014), wearable activity tracker-based interventions have the potential to prevent or slow-down the age-related declines in physical and cognitive functioning. Second, older adults are the fastest growing segment of the population regarding Internet use and smartphone ownership (Anderson & Perrin, 2017), which facilitates the potential adoption of wearable activity trackers in their daily lives. However, only a handful of intervention studies have used wearable activity trackers to promote PA in older adults. Cadmus-Bertram and colleagues (Cadmus-Bertram, Marcus, Patterson, Parker, & Morey, 2015) conducted a 16-week wearable activity tracker-based intervention and found it significantly increased the daily step counts by 789 among postmenopausal women. In contrast, another randomized controlled trial showed that a 24-week intervention combining wearable activity trackers with exercise counseling did not change the PA level in sedentary and overweight older adults (Thompson, Kuhle, Koepp, McCrady-Spitzer, & Levine, 2014). Since the findings from previous studies are mixed and limited, more research is needed to investigate the effectiveness of wearable activity tracker-based interventions and understand how to best implement these interventions in older adults. Such information will contribute to informing the design and implementation of effective interventions to promote PA among the older population in future studies. As far as we know, only a few studies have examined the acceptability of wearable trackers in older adults and most of them were conducted within a relatively short period (Nguyen et al., 2017; Rosenberg et al., 2016).

The purpose of the current study was to examine the effectiveness and acceptability of wearable activity trackers for promoting PA in older adults living retirement communities. It was hypothesized that using wearable activity trackers combined with self-regulatory techniques

(e.g., goal setting, self-monitoring, and feedback) would significantly improve the PA level and would be considered to be positive and acceptable among older adults. The majority of the older adults living in retirement communities were physically inactive as less than 15% of them meet the PA guidelines. The preliminary evidence of the current study would better inform how wearable activity trackers can help this population become more active.

Methods

Participants

Participants were 41 older adults voluntarily participating in a 12-week multicomponent PA intervention as part of a two-arm quasi-experimental trial. The multicomponent intervention had two major parts: wearing activity trackers combined with self-regulatory techniques and attending group exercise lessons (45-min each lesson, three lessons per week). The current study only focused on the former part. Detailed information regarding group exercise lessons would be described in Study 3.

Between May 2019 and August 2019, we recruited individuals from two retirement communities in southeast Michigan. Flyers were posted on community message boards and a 60-min on-site presentation was delivered to inform the procedures and benefits of participating in this study. Potential participants were screened for study eligibility using the criteria including: 1) aged 65 or older, 2) able to speak and read English fluently, 3) able to walk for 10 feet without human assistance, 4) scored 3 or greater in the Mini-Cog test, a screening test for cognitive impairment in older adults (Borson, Scanlan, Chen, & Ganguli, 2003). A total of 41 eligible individuals (mean (SD) age = 85.4 (5.1) years, 80.5% females) were voluntarily assigned to the intervention group in this study. All participants provided written informed consent before the

study and the research protocol was approved by the University Institutional Review Board (HUM00158279).

Intervention

Activity tracker training and wearing protocols. Each participant received a Fitbit (model InspireHR) activity tracker at the beginning of the study. The Fitbit activity tracker is a commercially available and non-invasive activity tracker worn similar to a watch on the wrist. A built-in accelerometer captures body movement and then is converted to several PA indicators such as steps, distance, and floors climbed. The activity tracker provides real-time visual feedback of these PA indicators for users. To minimize the potential barriers of using the activity tracker, participants were given a one-hour training before the intervention on how to operate the activity tracker, navigate its basic functions, and charge the battery. In addition, ongoing support was also provided by the research team to allow participants to report any issues in using the activity tracker during the 12-week intervention. Participants were asked to wear the activity tracker from Monday to Friday during their wake hours every week throughout the intervention and encouraged to frequently check their PA indicators on the activity tracker.

Goal setting. Setting an activity goal is an important predictor of increased PA (Bravata et al., 2007). Each participant was guided to set an individualized step-count goal with a plan for increasing average daily steps by 500 to 1500 steps every two weeks based on their baseline step counts, which eventually led to achieving or maintaining 7500 steps a day by the end of the intervention. For example, if a participant's average daily step counts in the previous two weeks ranged from 2500 to 3000, his or her goal for the next two weeks would be 4000 steps per day. If a participant did meet the previous goal, the subsequent goal of daily steps would not be increased. The ultimate goal of 7500 steps a day was set based on a recent study showing that the

risk of mortality in older adults decreases as daily step counts increase before leveling at 7500 steps per day (Lee et al., 2019). Every two weeks, each participant received a one-page weekly PA goal sheet to indicate their activity goals for the next two weeks (Figure 4.1).

Weekly individualized feedback. Each participant received weekly individualized feedback summarizing their daily step counts during the previous week (Figure 4.2). Although the activity tracker is associated with a mobile app that can track PA indicators, the majority of participants in the current study did not have access to a smartphone. Therefore, we created a Fitbit account and password for each participant. We collected each participant's activity tracker every weekend and synced the PA data to each participant's online account. The participants' daily step counts during the previous week were exported using the Fitabase analytics system (Small Steps Labs, San Diego, CA, USA) which allowed us to manage the activity tracker data for multiple participants. A personalized printout of feedback was reported and the activity trackers were returned to each participant before every Monday morning.

Measures

Demographics. Demographic information including age, gender, race, marital status (married/not married), and education (not graduate high school/high school graduate/bachelor degree or higher) was obtained at baseline using a questionnaire.

Daily step counts. Daily step counts were objectively measured by the activity tracker. The average daily step counts during the first week of the intervention were calculated as the baseline daily step counts. This was because the goal setting and feedback started in the second week of the intervention. The average daily step counts during the last two weeks of the intervention were computed as the endpoint daily step counts. Days in which the daily step counts less than 500 were considered non-wearing days and thus were excluded in the

calculation (Tudor-Locke, Giles-Corti, Knuiman, & McCormack, 2008). The Fitbit activity tracker has been demonstrated to accurately track steps in older adults (Paul et al., 2015). Data of daily step counts were stored and downloaded from the Fitabase analytics system.

Acceptance of activity trackers. At the end of the intervention, each participant completed an in-person assessment including a questionnaire and a semi-structured individual interview regarding their acceptance of using the Fitbit activity tracker. The 8-item Acceptance questionnaire with a 5-point rating scale was adapted from a previous study in which it was used in adults with chronic illness (Mercer et al., 2016). The questionnaire mainly focused on the perceived usefulness and perceived ease-of-use based on the Technology Acceptance Model (Davis, 1989). Participants rated on a 5-point Likert scale to indicate the extent to which they endorse each item from 1 (strongly disagree) to 5 (strongly agree). The internal consistency was good in the current study (Cronbach's alpha = 0.90). The detailed items were listed in Table 4.2.

A semi-structured individual interview was conducted with each participant to collect further information regarding their acceptance of using the activity tracker. The interview consisted of four questions asking participants to indicate what they liked or disliked about the activity tracker, what improvement could be made to make the activity tracker more useful to them, and whether they would continue using the activity tracker to monitor their activities. Each interview lasted 5 to 10 min and was audio-taped using a recorder. The interviews were conducted in a conference room in the retirement communities. Each interview was transcribed verbatim for later analysis.

Data Analysis

Baseline characteristics were described using descriptive statistics with mean and standard deviation for numerical variables and with frequency and percentage for categorical

variables. For the Acceptance questionnaire assessing the acceptance of using the activity tracker, the average score of each item was calculated. A paired t-test was conducted to examine the change of average daily step counts from baseline to endpoint with a significance level of $p < .05$ (no violation of normality was detected for the baseline daily step counts and endpoint daily step counts by checking the skewness and kurtosis). Cohen's d was calculated as an index of effect size by dividing the mean difference of daily step counts between baseline and endpoint by the standard deviation of baseline daily step counts. All quantitative analyses were performed in SPSS (version 26).

The interview transcripts were analyzed using the thematic analysis (Braun & Clarke, 2006). We chose thematic analysis because it does not require a pre-existing theoretical framework yet to organize and describe data in rich detail. First, the transcripts were read and re-read to generate initial codes. Second, the codes were collated and similar codes were gathered to form potential themes. Following this process, the themes were refined by reviewing the codes in each theme and connecting themes with each other to validate the similarities and dissimilarities. The qualitative data analysis was performed using the NVivo (version 12).

Results

Baseline characteristics

One participant dropped out of the study in the first week of intervention, reporting dissatisfaction on the accuracy of the activity tracker in recording step counts. The remaining forty participants completed the endpoint assessment and were included in the final analysis. The baseline characteristics of these participants were presented in Table 4.1. The average age of participants was 85.4 years (SD = 5.2) and more than half (55%) of them were 85 years or older.

The majority of participants were female (80%), had graduated from high school or above (95%), and were not married (67.5%). All of the participants were Whites.

Effectiveness

The average daily step counts of participants were 5063 ± 3049 at baseline and 5963 ± 3244 at the end of the intervention. The paired t-test revealed that this average increase of 900 steps per day was significant ($t = 3.56$, $p < 0.001$). Cohen's d was equal to 0.3, indicating a small effect size (Cohen, 1988).

Acceptability

Adherence to wearing the activity tracker. Data indicated that participants wore the activity trackers during 97.5% of the required days, suggesting high compliance with the intervention. One participant was replaced with a new activity tracker in the third week of the intervention due to a battery issue. Another two participants reported that the activity trackers did not display the time correctly in the fourth week and fifth week. Another participant reported having trouble navigating to the main screen of the activity tracker. Our research team fixed these issues immediately after receiving the request for assistance. No other technical issues were reported during the intervention.

Acceptance questionnaire. The average score of each item of the Acceptance questionnaire ranged from 3.83 for the item "I found the Fitbit clear and understandable to use" to 4.26 for the item "The weekly Fitbit's feedback (provided by the research team) was helpful" (Table 4.2). The average score was 4.00 for item 1 measuring the overall satisfaction with the wearable activity tracker. The mean score of all items was 4.00. The results of the Acceptance questionnaire indicated that participants considered the wearable activity trackers to be helpful and acceptable.

Individual interviews. Three overarching themes regarding the attitudes towards the wearable activity tracker emerged from the analysis of the interview transcripts. These were liked features, disliked features, and additional suggestions.

Theme 1: liked features

Self-awareness was the most frequently mentioned theme in the interviews. When asked what they liked about the activity tracker, 20 participants (50%) indicated that the activity tracker made them more aware of their walking/daily steps. For example, one participant commented:

> *Well I could find out how many steps I had walked because I don't purposefully go out and walk on the track or that sort of thing. So to know I'm getting some sort of walking in is good. (P33)*

Nine participants (22.5%) also mentioned that the activity tracker helped them monitor their heart rate. For instance, one participant commented:

> *Even that I'm not sure how good that would be. It works mainly on your heartbeat more than anything else. Going through your pulse doesn't mean that you are walking or running or swimming. Your pulse could be fast just because you are watching a program on TV that is getting you excited or you see a handsome man walking down the road and get excited. (P13)*

Checking the visual feedback from the activity tracker facilitated their PA behavior change through goal achievement. Eleven participants (27.5%) reported that being aware of their PA helped them achieve their activity goals more effectively. Note that this was different from awareness in that it evidently involved activity goals, although the goal achievement could be a consequence of self-awareness.

I could get my heartbeat, the date of course and the number of steps. The calories I didn't pay much attention to but the number of steps was important. I tried to gain my 7,500 and I didn't do it all the time. Like Monday I was sick and didn't get much out of bed. (P14)

Theme 2: disliked features

When asked about the disliked features of the activity tracker, eight participants (20%) reported that wearing the activity tracker was sometimes uncomfortable. The uncomfortable experience was mainly because the watchband of activity tracker was too tight or the skin touch with the metal part of the activity tracker was annoying.

It sticks. It doesn't move and that's part of the problem. My cuffs sometimes don't go over it. I have to keep it loose so it doesn't squeeze me. (P39)

Seven participants (17.5%) reported that they found it hard to read the visual feedback mainly because the numbers displayed on the activity tracker were too small.

If it were bigger so I could see it better. And I think if I had a bigger one it would be on more of my arm and record more accurately. (P25)

Theme 3: additional suggestions

When asked about the possible improvement that could make the activity tracker more useful to them, 12 participants (30%) expressed their interest in exploring other functions of the activity tracker, such as tracking water intake and sleep.

I don't know. I'd like some of the other settings. Like how much water you drink and so forth you could probably program it for that. I guess it has how many calories I've burned. (P20)

The activity tracker showed the potential for long-term use based on the interviews. The majority of participants (95%) expected that they would continue using the activity tracker.

Oh yes, I definitely will. I have blood clots in my lungs and the doctor said if I don't exercise I'll have more. (P24)

Only two participants (5%) reported they would not continue using the activity tracker. One indicated that the activity tracker was perceived inaccurate and the other indicated that he was not interested in the feedback the activity tracker provided.

I don't particularly like it. If it was bigger and recorded more accurately I would have used it. (P25)

Discussion

The current study examined the efficacy and acceptability of wearable activity trackers in promoting PA in older adults living in retirement communities. Findings from objectively measured PA indicated that the wearable activity tracker was effective in promoting PA in older adults. Results from the acceptance questionnaires and individual interviews indicated that the wearable activity tracker was an acceptable tool for older adults to self-track their PA.

Of the 40 participants who wore the activity tracker for 12 weeks and received weekly feedback and personalized goals, the average daily step counts increased by 900, equivalent to 18% of baseline daily step counts. Although the effect size (Cohen's d = 0.3) was small according to the commonly used interpretation, such an increase may be associated with significant health benefits for this population (A. V. Patel et al., 2018). The magnitude of the intervention effect was similar to a few previous studies. In their study involving older women aged 60 to 78 years, Koizumi and colleagues (2009) found that a 12-week intervention combining waist-worn activity trackers with bi-weekly feedback and progressive goal setting significantly increased participants' daily step counts by 16%. In another study, Cadmus-Bertram and colleagues (2015) conducted a 16-week Fitbit-based intervention with a fixed activity goal

of 10,000 steps per day in postmenopausal women. Participants in their study increased daily step counts by 13.3%. The findings from the current study support these studies showing that self-monitoring of PA combined with personalized goal setting and feedback led to a small but significant increase of PA in older adults.

Participants in the current study generally found the activity tracker to be satisfactory, useful, and easy to use after using it for 12 weeks. The activity tracker data were available for the majority of measured days, indicating the actual use of activity tracker was high. Results of the Acceptance questionnaire indicate that participants endorse more on the usefulness than the ease-of-use of the activity tracker, which are two key components of the Technology Acceptance Model. This was also reflected by a few reported cases of technical issues during the 12-week use of the activity tracker, as well as barriers identified in the interviews. The ease-of-use might be a priority focus for future interventions aiming at facilitating the adoption of wearable activity trackers in the older population. Although the current study included one session for guiding participants to use the activity tracker before the intervention and provided ongoing technical support, this might not be sufficient to eliminate technical barriers for older adult users. Future research may consider including more training sessions throughout the intervention.

The Acceptance questionnaire also shows that participants rated most highly on the weekly feedback of step counts provided by our research team. This suggests that feedback over a period of time provides additional value in increasing older adults' perceived usefulness of the activity tracker on top of the instant feedback. It should be noted that feedback over days or weeks could not be displayed on the activity tracker. Users need to sync their activity tracker data with a smartphone or computer via Bluetooth and access a mobile app or Website to review their past activity tracker data, which may cause additional effort for older adults. Nevertheless,

the rapidly increasing number of smartphone owners in the older population makes the large-scale adoption of the activity tracker in older adults promising in the future.

Self-awareness is the most prominent theme identified in the interviews. Being able to check their step counts throughout the day prompts changes in their PA behavior. This is in line with a few previous studies evaluating the use of activity trackers in older adults. In the study by Mercer and colleagues (2016) involving older adults with chronic illness, participants used four wearable activity trackers with each for three days and perceived that activity trackers helped them become more aware of their activity levels. That the activity tracker increases self-awareness and motivation of PA was also identified in men with prostate cancer who wore the Fitbit activity tracker for three weeks (Rosenberg et al., 2016) and breast cancer survivors who used two to three different activity trackers with each for two weeks (Nguyen et al., 2017). The current study supports these findings by expanding the length of using activity trackers to 12 weeks. Besides the increased self-awareness of PA, participants in the current study also liked having the ability to check their heart rate throughout the day. This was an unexpected finding because the heart rate was not the main focus of the current study. However, it has significant implications for future interventions such that integrating health indicators into the wearable activity tracker may facilitate its use in the older population. Manufacturers may consider improving the usefulness of the wearable activity tracker by expanding its capability of self-monitoring to other indicators that are critical to older adults, such as blood glucose and blood pressure, if it is technically feasible.

Comfort and ease of reading are important to older adult users of activity trackers, as several participants in the current study reported negative experiences in these two aspects. We also from time to time observed that some participants took up to a few minutes to wear the

activity tracker and adjust the watchband. When developing future activity trackers for older adults, it should be kept in mind that older adults generally have functional declines such as impaired vision and weakened muscle strength (Lunney, Lynn, Foley, Lipson, & Guralnik, 2003). Wearable activity trackers designed for older adults must be comfortable to wear, easy to operate, clear to understand, and avoid arousing unpleasant feelings.

The interviews also revealed participants' interest in using other functions of the activity tracker. Future research should investigate how to integrate all functions and features of the activity tracker to optimize PA interventions. For example, although not used in the current study, the mobile app and Website of the Fitbit activity trackers allow users to have a virtual social community and share their PA data with others in the social community. Competing with important others such as family and friends may also increase their motivation for PA, as one participant (P9) in the present study indicated that "*it is kinda like a game in a way because it encourages my husband and me to do more activity*."

Although the current study demonstrates that the activity tracker-based intervention is promising in promoting PA in older adults, several limitations should be noted. First, participants in the current study were relatively well-educated and consisted of all White, which limits our generalizability of the study results. Including older adults with different race/ethnicities and educational backgrounds in future studies would contribute to more diverse opinions toward the use of activity trackers in older adults. Second, our findings regarding the significant intervention effect in increasing daily steps might be conservative for two reasons. On the one hand, the activity tracker in the current study was both an intervention component and an assessment tool of baseline daily step counts. Therefore, participants might be inadvertently exposed to a certain extent of the intervention during the baseline measure of daily step counts. This might in turn

lead to the underestimation of the intervention effect, although evidence shows owning the activity tracker alone is unlikely to elicit behavior change (M. S. Patel, Asch, & Volpp, 2015). On the other hand, the current study did not exclude participants who were already physically active. We suggest future studies target specifically inactive older adults and objectively measure the PA (e.g., using accelerometers) before the activity tracker is given to participants. Third, because the participation of the current study was completely voluntary, participants may already hold a positive attitude towards the activity tracker before the intervention. Future studies should seek to examine the effects of activity trackers on PA among older adults who have low interest in using wearable activity trackers. Fourth, wearing activity trackers combined with self-regulatory techniques was not the only part of the intervention. The inference of the results was under the assumption that the effects of group exercise lessons on daily step counts were similar at baseline and at the end of the intervention because the number and format of group exercise lessons were consistent every week throughout the intervention. Nevertheless, group exercise lessons could still partially confound the effect of wearing activity trackers combined with self-regulatory techniques on daily step counts in the participants. Last but not least, we did not conduct follow-up evaluations regarding the long-term use of the activity tracker, especially after stopping providing the weekly feedback. Nevertheless, we believe it is promising for continuous long-term use of the activity tracker by the participants because all but two of them expressed intention of continuing using the activity tracker to monitor their activities.

Conclusion

The current study provides preliminary evidence that activity trackers, combined with behavior change techniques, are effective in promoting PA and acceptable to the older population. Older adults manifest high adherence to wearing and using the activity tracker, find

the activity tracker to be helpful in enhancing self-awareness and PA motivation, and express intention for continuing using the activity to monitor their activities. Future designs of activity trackers targeting older adults could make the interface easier to read and require less fine motor skills to operate the activity tracker. In light of the rapidly growing older population, wearable activity trackers have significant potential to be a cost-effective and sustainable tool for promoting PA and improving health for older adults.

Table 4.1 Demographic characteristics of participants

		n (%)
Age	75-84	18 (45%)
	>=85	22 (55%)
Gender	Male	8 (20%)
	Female	32 (80%)
Education	Did not graduate high school	2 (5%)
	High school graduate	21 (52.5%)
	Bachelor degree or higher	17 (42.5%)
Marital Status	Married	13 (32.5%)
	Not married	27 (67.5%)
Race	White	40(100%)

Table 4.2 Items and scores of the Acceptance questionnaire

Item	Mean (score range 1-5)	SD
Overall, I was satisfied with the Fitbit.	4.00	0.83
Using the Fitbit kept me more active.	4.10	0.71
Using the Fitbit helped me set activity goals.	3.92	0.83
Setting the activity goals helped me be more active.	4.03	0.64
Using the Fitbit helped me reach my activity goals.	3.90	0.79
The weekly Fitbit's feedback (provided by the research team) was helpful.	4.26	0.68
I found the Fitbit clear and understandable to use.	3.83	0.75
Overall, the Fitbit is easy to use.	3.95	0.75

Figure 4.1 An example of bi-weekly activity goal

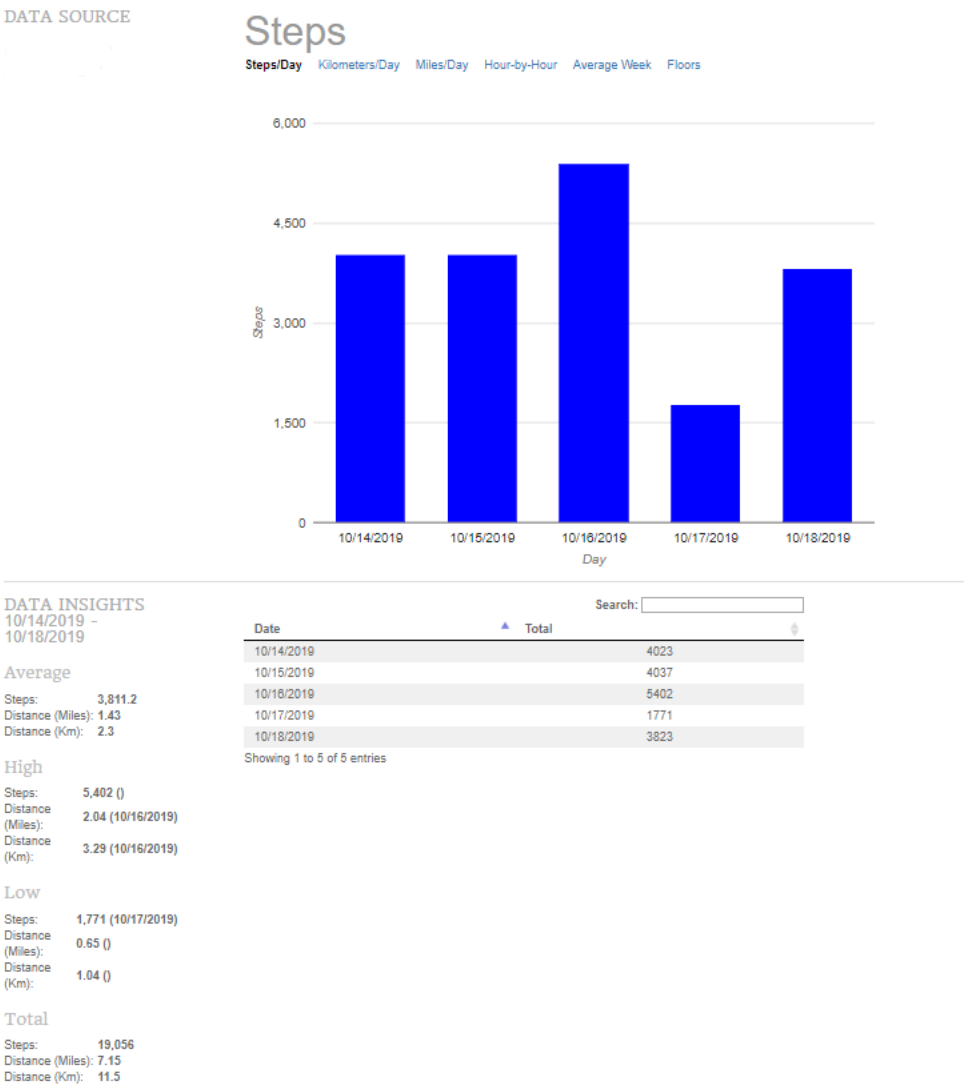

Figure 4.2 An example of weekly feedback of daily steps

Chapter 5

Impact of a Multicomponent Physical Activity Intervention on Psychological Well-Being in Older Adults

Abstract

Objective: To examine the impact of a multicomponent PA intervention on different dimensions of psychological well-being in older adults living in retirement communities.

Methods: Fifty-nine participants (mean age = 83.8 years, 76.3% female) living retirement communities were voluntarily assigned to a 12-week multicomponent PA intervention program or an attention control group. Participants in the intervention group were asked to take three 45-min supervised group exercise lessons per week and wear wearable activity trackers during the weekdays for 12 weeks. Four components of psychological well-being were assessed at baseline and the end of the intervention including life satisfaction, happiness, eudaimonic well-being, and depressive symptoms. The intervention effect on each component of psychological well-being was analyzed using linear mixed models after controlling for potential confounders.

Results: Participants in the intervention group on average attended 86.9% of group exercise lessons and wore the activity trackers on 97.5% of the required days. The linear mixed models revealed a significant positive intervention effect on happiness such that the happiness improved in the intervention group but decreased in the comparison group. However, there was no significant difference between the two groups in terms of the changes in life satisfaction, eudaimonic well-being, and depressive symptoms.

Conclusions: The multicomponent PA intervention is effective in improving happiness in older adults living in retirement communities. Future research is suggested to incorporate more comprehensive intervention programs targeting all dimensions of psychological well-being in older adults.

The US population is aging rapidly. The number of Americans aged 65 and older is projected to nearly double from 50 million now to 95 million by 2060, comprising 23% of the total population by that time (U.S. Census Bureau, 2018b). As aging is generally associated with a decline in physical and cognitive functioning and an increase in chronic conditions, the increasing number of older adults will lead to the rising cost of medical care (Hagen, 2013). In addition to age-related declines in health, the change in the social environment, such as retirement and social isolation, also negatively impacts psychological well-being in older adults (Snowden, Dhingra, Keyes, & Anderson, 2010). Maintaining high levels of psychological well-being is considered as a critical part of "successful aging" (Blazer, 2006). For example, there is robust evidence showing that high levels of psychological well-being are associated with a reduced risk of functional disability, various chronic diseases, and all-cause mortality (Chida & Steptoe, 2008; Diener & Chan, 2011). Therefore, identifying potentially modifiable factors that are associated with psychological well-being in later life has considerable public health importance for the aging society.

PA has been identified as one of the promising modifiable factors linked to psychological well-being in older adults. For example, considerable epidemiological and experimental research has shown that PA can be used to prevent and treat depression and anxiety in older adults (Chodzko-Zajko et al., 2009). However, previous studies have largely focused on the relationship between PA and negative aspects of psychological well-being such as mental disorders, whereas less research has addressed the relationship between PA and positive aspects of psychological well-being in older adults. Psychological well-being is a comprehensive concept including both negative and positive psychological characteristics (Keyes, 2007; Ryan et al., 2008). With respect to the positive dimension of psychological well-being, hedonic well-being and

eudaimonic well-being are two major approaches to operationalizing positive well-being. Hedonic well-being refers to the pleasure attainment and focuses on the subjective experience of happiness and life satisfaction (Ryan & Deci, 2001). Eudaimonic well-being refers to the degree to which a person is fully functioning and focuses on meaning, good relationships with others, and self-realization (Ryan & Deci, 2001). Eudaimonic well-being is commonly operationalized as consisting of six psychological domains including purpose in life, autonomy, personal growth, environmental mastery, positive relations, and self-acceptance (Ryff, 1989). Hedonic well-being and eudaimonic well-being are important aspects of healthy aging and both related to a range of health outcomes independent of negative aspects of psychological well-being. For example, a longitudinal study found that happiness was inversely associated with mortality among 1012 older adults during 15 years of follow-up (Koopmans, Geleijnse, Zitman, & Giltay, 2010). Another longitudinal study found that eudaimonic well-being, assessed by autonomy, sense of control, and purpose in life, predicted a lower risk of all-cause mortality among 9050 older adults with an average follow-up of 8.5 years (Steptoe et al., 2015).

Previous studies examining the relationship between PA and hedonic well-being and eudaimonic well-being in older adults also showed promising findings. For example, Kim and colleagues (2016) found that higher levels of self-reported leisure-time PA were associated with higher levels of life satisfaction and positive affect in older adults with loneliness. In older adults diagnosed with osteoporosis, leisure-time PA was found to be positively associated with eudaimonic well-being (Gunnell et al., 2011). However, previous studies investigating the relationship between PA and positive psychological well-being in older adults are mainly observational in nature (Zhang & Chen, 2019a). More research on investigating interventions that improve hedonic well-being and eudaimonic well-being is warranted. In addition, to the best

of our knowledge, no study has examined the impact of PA interventions on hedonic well-being and eudaimonic well-being among older adults living in retirement communities. A retirement community, also called continuing care retirement community, offers different types of housing and services (such as assisted living and independent housing) for older adults based on their needs (Centers for Medicare and Medicaid Services, 2015). The retirement community has become an increasingly popular housing option for older adults (Kluge, 2015). Previous evidence suggests that less than 15% of older adults living in the retirement communities are physically active according to the national guidelines for PA (Kerr et al., 2013; Pollard, Taylor, & Smith, 2001). The average age of residents in retirement communities is between 85 and 87 years, which falls in the range of the "oldest old" (Zebolsky, 2014). From a lifespan perspective, cross-sectional and longitudinal studies have consistently reported psychological well-being declines after age 80 (Berg, Hoffman, Hassing, McClearn, & Johansson, 2009; Gwozdz & Sousa-Poza, 2010; Smith, Borchelt, Maier, & Jopp, 2002; Zebolsky, 2014). Therefore, studying the relationship between PA and psychological well-being may help to design effective health promotion interventions in this population.

Previous intervention studies examining the effects of PA on psychological well-being, mainly negative aspects, have predominantly adopted supervised, group-based exercise programs such as aerobic or strength training classes and have shown promising results (Netz, Wu, Becker, & Tenenbaum, 2005). While walking has been identified as the favorite type of exercise in older adults (Stathokostas & Jones, 2016), relatively few intervention studies have investigated the impact of walking on psychological well-being in the older population. For example, Fisher and Li (2004) found that a 6-month neighborhood walking program significantly improved life satisfaction in older adults. Recently, emerging research using wearable activity trackers offers

significant promise for promoting walking in older adults. For example, Cadmus-Bertram and colleagues (2015) found that older adults who used Fitbit activity trackers for 16 weeks increased daily steps by 798 on average. As far as we know, no existing study has examined the impact of a combined intervention of supervised exercise lessons and walking on psychological well-being in older adults. The 2018 Physical Activity Guidelines suggest that older adults would gain more health benefits from multicomponent PA including aerobic endurance, strength, balance, and flexibility (US Department of Health and Human Services, 2018). Therefore, it is possible that multicomponent PA would also have a greater impact on psychological well-being in older adults.

Taken together, the purpose of the current study was to examine the effect of a 12-week multicomponent PA intervention on life satisfaction, happiness, eudaimonic well-being, and depressive symptoms, reflecting different dimensions of psychological well-being, in older adults living in retirement communities. It was hypothesized that the multicomponent PA intervention would benefit each dimension of psychological well-being in the intervention group compared to the comparison group. The findings of this study would expand the current knowledge on the relationship between PA and psychological well-being by combining supervised exercise programs and wearable activity trackers as intervention components and assessing both positive and negative dimensions of psychological well-being.

Method

Study Design and Participants

The current study used a two-arm, quasi-experimental design. We recruited individuals from two retirement communities in southeast Michigan. With the assistance of administrators and staff members in the retirement communities, flyers were distributed, and potential

participants were invited to attend an on-site presentation introducing the current study. Eligibility criteria were being aged 65 or older, able to walk for 10 feet without human assistance, able to speak and read English fluently, and scored 3 or greater in the Mini-Cog test, a screening test for cognitive impairment in older adults (Borson et al., 2003). Previous research showed that the recruitment rate to PA intervention research was low in older adults living in retirement communities (Duckham et al., 2018). In addition, due to the limited funding of the current study, participants were assigned to the intervention group or comparison group with their own preference. A total of 59 eligible individuals (mean age = 83.83 $\pm$6.6 years, 76.3% females) participated in this study. Among these participants, 41 were in the intervention group and 18 were in the comparison group. It should be noted that the participants in the intervention group were the same participants included in Study 2. Written informed consent was obtained from all participants before the study. The research protocol was approved by the University Institutional Review Board (HUM00158279).

Intervention

Group exercise lessons. The intervention group received three, 45-min group exercise lessons for 12 weeks. The group exercise lessons were taught by two experienced instructors. A typical group exercise lesson consists of 10-min warm-up (i.e., stretching exercises and walking in place), 30-min functional fitness exercises (i.e., muscle strengthening, balance, and coordination), and 5-min cool-down (i.e., stretching and breathing). The design of group exercise lessons was based on the 2018 Physical Activity Guidelines' recommendation that older adults should participate in multicomponent PA that includes aerobic exercises, muscle strengthening exercises, flexibility exercises, and balance training.

Wearable activity trackers with feedback and goal setting. Each participant in the intervention group received a Fitbit (Model InspireHR) activity tracker to self-monitor their daily PA, 5 days per week for 12 weeks. The Fitbit activity tracker is a commercially available and noninvasive activity tracker that is worn on the wrist and captures several PA indicators such as steps, distance, and floors climbed. These indicators could be displayed on the device to provide instant feedback for users. The research team delivered a one-hour presentation before the intervention to introduce the basic features of the trackers, assist participants to initialize their trackers, and guide them to operate their trackers. Since most of the participants did not use a smartphone, the research team set up a Fitbit account for each participant. Participants were asked to wear the activity trackers from Monday to Friday to track their PA. The research team collected participants' trackers every weekend and returned the trackers to participants before the next Monday morning. Each participant received a Weekly Individual Report (one-page paper with graphs and numbers) showing their daily steps during the previous week. Collecting trackers every week also allowed us to provide ongoing assistance for participants regarding the use of the activity tracker. In addition, we incorporated a goal-setting strategy as an intervention component. Each participant was given a personalized step-count goal for increasing their daily step counts by 500 to 1500 every two weeks, toward an ultimate goal of 7500 steps per day (Lee et al., 2019). Participants who reached 7500 steps per day during the intervention were asked to maintain their PA level till the end of the intervention.

The comparison group continued their usual activities but received bi-weekly newsletters that addressed topics related to PA and health.

Measures

During the first two weeks of September 2019, the research team administered a questionnaire assessing major outcomes including life satisfaction, happiness, eudaimonic well-being, and depressive symptoms, and covariates including sociodemographic information, self-rated health, and PA, as well as a functional mobility test, to each participant in the intervention group and the comparison group. After the 12-week intervention, the research team again administered the same questionnaire for life satisfaction, happiness, eudaimonic well-being, and depressive symptoms to each participant in the two groups.

Life satisfaction. Life satisfaction was measured as the cognitive component of hedonic well-being using the Satisfaction With Life Scale (SWLS, Appendix B) (Diener, Emmons, Larsen, & Griffin, 1985). The SWLS contains five items designed to measure an individual's global judgment of life satisfaction (e.g., "In most ways my life is close to my ideal") Respondents were asked to rate the extent to which they agree with or disagree with each statement on a 7-point Likert scale. The sum of all items provides a composite score, with higher scores representing higher levels of life satisfaction. Previous studies have demonstrated satisfactory reliability and validity of SWLS for the use in older adults (Pavot, Diener, Colvin, & Sandvik, 1991). The internal consistency was satisfactory in the present study (Cronbach's alpha = 0.85).

Happiness. Happiness was measured as the affective component of hedonic well-being using the Subjective Happiness Scale (SHS, Appendix C) (Lyubomirsky & Lepper, 1999). The SHS is a 4-item questionnaire asking respondents to rate the extent to which each statement (e.g., "In general, I consider myself a very happy person") was appropriate in describing them on a 7-point Likert scale. The mean score of all items was calculated to indicate the level of happiness with higher scores indicating greater happiness. The SHS has been demonstrated to be valid and

reliable in older adults (Angner, Ghandhi, Purvis, Amante, & Allison, 2013). In the present study, Cronbach's alpha value was 0.78 for the SHS.

Eudaimonic well-being. Eudaimonic well-being was assessed using the 18-item Psychological Well-Being Scale (PWBS, Appendix D) (Ryff, 1989). The PWBS consists of six 3-item subscales measuring autonomy, personal growth, environmental mastery, positive relations with others, purpose in life, and self-acceptance. Respondents were asked to rate the extent to which they agree with or disagree with each statement (e.g., "Some people wander aimlessly through life, but I am not one of them") on a 7-point Likert scale. An index was computed by first summing items in each subscale and then averaging the scores of all subscales. Higher scores indicate higher levels of eudaimonic well-being. Previous studies have provided support for the validity and reliability of the use of PWBS in older adults (Andrew et al., 2012; Clarke, Marshall, Ryff, & Wheaton, 2001). In the current study, Cronbach's alpha values ranged from 0.5 to 0.7 for the six subscales while the Cronbach's alpha value for all of the 18 items was 0.84, supporting the use of a single index for eudaimonic well-being.

Depressive symptoms. Depressive symptoms were assessed using the short version of the Centre for Epidemiological Studies Depression Inventory (CESD-R, Appendix E) (Radloff, 1977). The CESD-R consists of ten items pertaining to symptoms of depression, such as "I was bothered by things that usually don't bother me." Respondents were asked to rate how often they experience each symptom during the past week on a 4-point Likert scale. The level of depressive symptoms was reflected by summing the responses of the ten items, with higher scores indicating greater levels of depressive symptoms and a cutoff score of 10 or higher indicating significant depressive symptoms. Previous studies have demonstrated that the CESD-R is a reliable and valid measure for assessing depressive symptoms in older adults (Andresen,

Malmgren, Carter, & Patrick, 1994; Irwin, Artin, & Oxman, 1999). The internal consistency in this study was 0.79.

Covariates. Baseline age, gender, marital status (married/not married), education (not graduate high school/high school graduate/bachelor degree or higher), body mass index (BMI), self-rated health, functional mobility, and PA were measured to minimize potential self-selection bias. BMI was computed from self-report height and weight (kg/m^2). Self-rated health was measured using a single-item question "Would you say in general your health is poor, fair, good, very good, or excellent?" The response options ranged from 1 (poor) to 5 (excellent). This sing-item question has been shown to be a valid measure of health status and is related to the mortality and morbidity of various diseases (DeSalvo, Bloser, Reynolds, He, & Muntner, 2006). Functional mobility was assessed using the Timed Up and Go (TUG) test (Podsiadlo & Richardson, 1991), which times a participant standing up from a chair, walking 3 meters, turning, walking back to the chair, and sitting down again, with less time indicating higher levels of functional mobility. PA was measured using the validated International Physical Activity Questionnaire - Short Form (IPAQ), which assesses the frequency and duration of vigorous-intensity PA, moderate-intensity PA, and walking in the past week (Craig et al., 2003). The metabolic equivalents (MET) minutes per week were calculated according to the standard scoring procedures for the IPAQ, with greater MET-minutes per week indicating higher levels of PA.

Process evaluation. To assess the adherence to group exercise lessons, each participant's attendance was recorded and calculated by dividing the number of lessons attended by the number of lessons taught. To measure the compliance of wearing Fitbit trackers, the percentage of days wearing it was calculated for each participant using the Fitabase analytics system (Small

Steps Labs, San Diego, CA, USA) which allows investigators to manage the Fitbit data for multiple participants.

Data Analysis

Descriptive statistics including means with standard deviations for numerical variables (i.e., age, self-rated health, BMI, functional mobility, PA, and psychological well-being outcomes) and counts with percentages for categorical variables (i.e., gender, education, marital status) were used to present the baseline characteristics of participants. One participant in the intervention group withdrew from the study in the first week due to dissatisfaction with the accuracy of the Fitbit activity tracker, and thus was excluded from the final analysis. The skewness and kurtosis of all numerical variables were checked for normality, with an absolute skew value greater than 2 and/or an absolute kurtosis value greater than 7 indicating a substantial departure from normality (Curran, West, & Finch, 1996). For the non-normal variables, possible transformations (e.g., log transform, square transformation, dichotomizing) would be applied. The results showed that all the numerical variables were within the acceptable range of skewness and kurtosis, and thus no transformation was performed. Due to the unbalanced sample size between the two groups, Welch's t-test, which does not rely on the assumption of equal variance, was used to compare the numerical variables at baseline between the intervention group and the comparison group (Delacre, Lakens, & Leys, 2017). The differences of categorical variables at baseline between two groups were examined using the Chi-square test.

To examine the intervention effect on psychological well-being, several linear mixed models were conducted due to the repeated nature of the study design and the unbalanced sample size between the two groups. The psychological well-being outcomes, life satisfaction, happiness, eudemonic well-being, and depressive symptoms, were treated as the dependent

variables of these models, respectively. The independent variables of each model included the main effect of time (baseline vs. posttest), the main effect of group (intervention vs. comparison, dummy coded), and the interaction term between time and group. In addition, the covariates which were significant at baseline between two groups were controlled for in each model. Statistically significant level for all analyses is set at $p < 0.05$. All of the quantitative data analyses were performed using R version 3.5.

Results

Table 5.1 shows the baseline characteristics and their differences between the two groups. Of the 58 participants who remained in the study, the mean age was 83.4 ± 6.61 years and more than half (51.7%) of the participants aged 85 years or older. Females counted 76% of the participants and all participants were Caucasian. Thirty-eight percent of the participants were married and near half (48.3%) of the participants were college graduates.

The Welch's t-tests and Chi-square tests revealed no significant differences between the intervention group and the comparison group at baseline except for the age and life satisfaction. Specifically, participants in the intervention group were older (85.4 vs. 80.3 years, $p = 0.025$) and had a higher level of life satisfaction (29.86 vs 23.81, $p = 0.001$) than the comparison group. In addition, there was a marginally significant difference ($p = 0.059$) in the self-rated health between the intervention group ($\bar{X} = 3.43$) and the comparison group ($\bar{X} = 3.00$). Therefore, age, life satisfaction, and self-rated health at baseline were controlled for in the linear mixed models as covariates. For participants assigned in the intervention group, the average attendance rate of group exercise lessons was 86.9%, and they on average wore the Fitbit activity trackers on 97.5% of the required days, indicating good fidelity to the intervention.

Table 5.2 shows psychological well-being outcomes at baseline and post-test between the intervention group and the comparison group. Table 5.3 presents the results of linear mixed models of intervention effects on the psychological well-being outcomes. Regarding happiness, the linear mixed model showed that there was no main effect of group (β = 0.17, p = 0.29) but a significant main effect of time (β = -0.31, p = 0.03). In addition, this main effect was overshadowed by a significant interaction between group and time (β = 0.42, p = 0.02), suggesting that the change of happiness from baseline to posttest was different between the two groups. Specifically, while the mean score of happiness of the intervention group increased from 5.65 to 5.76, the mean score of happiness of the comparison group decreased from 5.21 to 4.90, indicating a positive intervention effect on happiness.

Regarding the life satisfaction, the linear mixed model revealed a significant main effect of group (β = 0.90, p < 0.001), but no main effect of time (β = 0.10, p = 0.56). In addition, there was no interaction between group and time (β = -0.26, p = 0.20). The results indicated that the intervention group had overall a higher level of life satisfaction compared with the comparison group.

As shown in Table 5.3, the linear mixed models showed similar results for eudaimonic well-being and depressive symptoms. There was no significant main effect of time and group, and no significant interaction between time and group for eudaimonic well-being and depressive symptoms (p's > 0.05). Regarding the covariates controlled in each model, self-rated health was positively associated with life satisfaction (β = 0.39, p < 0.001). Life satisfaction at baseline was a significant covariate of happiness (β = 0.56, p < 0.001), eudaimonic well-being (β = 0.35, p = 0.02), and depressive symptoms (β = -0.28, p < 0.001), indicating higher levels of life

satisfaction associated with higher levels of happiness and eudaimonic well-being and lower levels of depressive symptoms.

Discussion

In the current study, we investigated the effects of a 12-week multicomponent PA intervention on both positive and negative dimensions of psychological well-being among older adults living in retirement communities. The results revealed that the effects of the intervention on different components of psychological well-being were inconsistent. Specifically, our study showed a positive intervention effect on happiness, but not on life satisfaction, eudaimonic well-being, and depressive symptoms.

Supporting our findings, a recent systematic review has shown a positive relationship between PA and happiness in older adults (Zhang & Chen, 2019b). Tse and colleagues (2014) found that an 8-week stretching and balancing exercise intervention with 60 min each time and once per week significantly improved happiness in the intervention group but not in the usual care group among older adults living in nursing homes. In another study, McAuley and colleagues (2000) found that both aerobic exercises and stretching exercises, with 40 min each time and three times per week, led to a significant increase in happiness after 6 months. Furthermore, they found there was no significant difference in the effect on happiness between the two types of exercise. As the affective component of hedonic well-being, happiness may be improved by frequent experiences of enjoyment and pleasure induced by participation in PA (Diener, Sandvik, & Pavot, 2009; Salmon, Owen, Crawford, Bauman, & Sallis, 2003). However, it should be noted that the magnitude of improvement in happiness in the intervention group was relatively small (5.65 vs. 5.76). Therefore, the results should be interpreted with caution as the

positive effect of the PA intervention on happiness was reflected in maintaining high levels of happiness rather than substantially improving happiness.

The current study did not show a positive intervention effect on life satisfaction. Previous studies investigating the relationship between PA and life satisfaction in older adults reported mixed findings (Rejeski & Mihalko, 2001). For example, in a recent randomized controlled trial, Yu and colleagues (2020) found that a 12-week exercise intervention, including two, 60-min group exercise lessons per week consisting of aerobic exercises and resistance training, had no impact on life satisfaction in older adults with an average age of 62.2 years. The lack of consistent evidence showing the positive relationship between PA and life satisfaction in older adults may be explained by two reasons. First, compared with happiness, life satisfaction is a more stable component of psychological well-being reflecting evaluations across the life-course and thus is less subject to change (Schimmack, Diener, & Oishi, 2002). Second, interventions targeting PA alone may not be sufficient to alter the level of life satisfaction in older adults. Previous studies have identified a range of determinants of life satisfaction in older adults such as social support and cognitive functions (St. John & Montgomery, 2010; Yeung & Fung, 2007). A recent study found that an active aging program targeting social engagement, PA, and cognitive functions significantly improved life satisfaction in institutionalized older adults (Buedo Guirado, Rubio Rubio, Dumitrache, & Romero Coronado, 2020). Therefore, it might be promising for future research to examine the effect of more comprehensive interventions on life satisfaction in older adults.

To date, relatively few studies have examined the relationship between PA and eudaimonic well-being in older adults. Although a handful of cross-sectional studies showed a positive relationship between PA and eudaimonic well-being (Gunnell et al., 2011; Ju, 2017; J.

Kim et al., 2017), the findings from the current study do not support this positive relationship. Only one previous experimental study (Conradsson et al., 2010) has examined the effects of exercises on eudaimonic well-being in older adults and the findings were consistent with the findings of the current study. In their study, Conradsson and colleagues (2010) conducted a 13-week high-intensity weight-bearing exercise intervention and found there was no difference in the change of eudaimonic well-being between the intervention group and the control group. It is possible that the positive relationship between PA and eudaimonic well-being in older adults observed in cross-sectional studies is caused by the reverse causality. As supported in a recent longitudinal study, Rector and colleagues (2019) found that the odds of maintaining high levels of PA were significantly higher for those with higher eudaimonic well-being.

Inconsistent with previous studies showing that exercises have a robust effect on reducing depressive symptoms in older adults (Chodzko-Zajko et al., 2009), the current study found no intervention effect on depressive symptoms. The lack of intervention effect on depressive symptoms in the current study may be explained by the ceiling effect, because the average score of depressive symptoms was low at baseline for participants in the intervention group. Future research is suggested to exclusively include older individuals with major depression or subsyndromal symptomatic depression.

A number of limitations associated with this study should be noted. First, a non-randomized sampling was used in the group assignment, which may lead to the self-selection bias, even though we have controlled for covariates at baseline that were significantly different between the two groups. Second, the sample in the current study consisted of all white, non-Latino older adults, which limits the generalizability of the results to older adults of other race/ethnicities. Third, the findings of the current study are limited to a 12-week period. Future

research is suggested to conduct long-term follow-up assessment to examine the maintenance of psychological well-being after having carried out exercise interventions. Fourth, the effect of each component of the intervention (group exercise lessons, wearable activity trackers with self-regulatory techniques) was not independently examined and thus no conclusion can be made as to which component is more or less effective than the other. Despite these limitations, the current study has strengths in measuring different dimensions of psychological well-being, adopting the multicomponent PA intervention, and targeting older adults living in retirement communities, which contributes to the theoretical and empirical literature of PA and health promotion in older adults.

Conclusion

In summary, the results of the current study show that a 12-week multicomponent PA intervention including group exercise lessons and wearable activity trackers with self-regulatory techniques is effective in improving happiness but has no impact on life satisfaction, eudaimonic well-being, and depressive symptoms among older adults living in retirement communities. This selective impact on different components of psychological well-being suggests that future studies may consider incorporating more comprehensive intervention components targeting all dimensions of psychological well-being, as each of them is a key aspect of healthy aging and independently related to a range of health outcomes in older adults.

Table 5.1 Baseline characteristics of participants

	Intervention group (n=40)	Comparison group (n=18)	Total (n=58)	*p* value
Age (years)	85.4(5.18)	80.3(8.16)	83.4(6.61)	0.025*
65-74	0 (0%)	5 (27.8%)	5 (8.6%)	
75-84	18 (45%)	5 (27.8%)	23 (39.7%)	
>=85	22 (55%)	8 (44.4%)	30 (51.7%)	
Gender				0.327
Male	8 (20%)	6 (33.3%)	14 (24.1%)	
Female	32 (80%)	12 (66.7%)	44 (75.9%)	
Education				0.189
Did not graduate high school	2 (5%)	1 (5.6%)	3 (5.2%)	
High school graduate	21 (52.5%)	6 (33.3%)	27 (46.6%)	
Bachelor degree or higher	17 (42.5%)	11 (61.1%)	28 (48.3%)	
Marital Status				0.204
Married	13 (32.5%)	9 (50%)	22 (37.9%)	
Not married	27 (67.5%)	9 (50%)	36 (62.1%)	
Self-rated health	3.43 (0.75)	3.00 (0.84)	3.29 (0.79)	0.059
BMI	27.20 (6.12)	28.87 (18.00)	27.72 (6.14)	0.345
Functional mobility	11.08 (2.83)	12.95(5.01)	11.59 (3.60)	0.191
Physical activity (MET minutes/week)	1195.0 (752.3)	828.1 (805.84)	1081.1 (781.2)	0.112
Life satisfaction	29.86 (4.19)	23.81 (6.36)	27.98 (5.67)	0.001**
Happiness	5.65 (0.89)	5.21 (1.14)	5.51 (0.98)	0.156
Eudaimonic well-being	16.26 (2.43)	15.32 (2.19)	15.97 (2.38)	0.154
Depressive symptoms	7.58 (5.08)	9.65 (5.51)	8.21(5.25)	0.206

*: $p < .05$; **: $p < .01$; ***: $p < .001$

Table 5.2 Means and standard deviations of psychological well-being outcomes at baseline and posttest

	Intervention group		Comparison group	
	Baseline	Posttest	Baseline	Posttest
Life satisfaction	29.86 (4.19)	28.98 (4.13)	23.81 (6.36)	24.33 (633)
Happiness	5.65 (0.89)	5.76 (0.87)	5.21 (1.14)	4.90 (1.07)
Eudaimonic well-being	16.26 (2.43)	16.41 (2.09)	15.32 (2.19)	16.04 (2.18)
Depressive symptoms	7.58 (5.08)	6.33 (4.38)	9.65 (5.51)	9.81 (6.65)

Table 5.3 Standardized coefficients (standard error) of linear mixed models (fixed effects only)

	Life Satisfaction		Happiness		Eudaimonic well-being		Depressive symptoms	
	β	SE	β	SE	β	SE	β	SE
Time	0.10	0.16	-0.31*	0.14	0.32	0.19	0.05	0.19
Group	0.90***	0.25	0.17	0.29	0.17	0.33	0.20	0.29
Time × Group	-0.26	0.20	0.42*	0.17	-0.25	0.23	-0.28	0.23
Age	0.00	0.11	-0.01	0.11	-0.12	0.12	0.02	0.11
Self-rated health	0.39***	0.10	0.04	0.11	-0.05	0.13	-0.19	0.11
Baseline life satisfaction			0.56***	0.13	0.35*	0.14	-0.46***	0.12

*: $p < .05$; **: $p < .01$; ***: $p < .001$

Chapter 6

Dissertation Conclusion

A growing number of studies have investigated the relationship between PA and psychological well-being in older adults. While consistent findings have established a positive association between PA and negative mental health outcomes such as depression and anxiety, research on the relationship between PA and positive psychological well-being is just beginning to accumulate. This dissertation extended existing research by conducting three separate but related studies to examine the relationship between PA and different dimensions of psychological well-being in older adults.

The first study investigated the possible bidirectional relationship between PA and purpose life, the latter of which is a key component of eudaimonic well-being and related to an array of health outcomes in older adults. The purpose of this study was to provide information regarding the causal precedence between PA and purpose in life in older adults. Using longitudinal data collected at three time points across eight years, a series of cross-lagged models were tested. Key findings of this study were that higher levels of purpose in life were associated with higher levels of subsequent vigorous-intensity PA, moderate-intensity PA, and light-intensity PA in older adults, but none of the PA variables predicted subsequent purpose in life. The hypothesis of a bidirectional relationship between PA and purpose life in older adults was not supported in this study. The positive association between PA and purpose in life observed in

previous cross-sectional studies may mainly result from the positive effect of purpose in life on PA rather than vice versa.

The second study and the third study were based on a 12-week multicomponent PA intervention in older adults living in retirement communities. The intervention components included supervised group exercise classes and using wearable activity trackers combined with providing weekly feedback and setting activity goals. The second study examined the effectiveness and acceptability of using wearable activity trackers to promote PA in older adults. Key findings of the second study were that the average daily step counts of participants receiving the intervention increased by 900 from baseline to the end of the intervention. Wearable activity trackers were perceived useful and easy-to-use to self-monitor older adults' PA.

The third study examined the effect of the 12-week multicomponent PA intervention on different dimensions of psychological well-being, including life satisfaction, happiness, eudaimonic well-being, and depressive symptoms. Key findings of the third study were that the positive effect of the intervention was only observed in happiness but not in life satisfaction, eudaimonic well-being, and depressive symptoms. Specifically, the level of happiness increased in the intervention group before and after the intervention while decreased in the comparison group.

In summary, the findings of this dissertation suggest that PA may have a selective association with different dimensions of psychological well-being. Specifically, PA may be more likely to have a positive effect on hedonic well-being but not eudaimonic well-being, as consistently implied in the first study and the third study.

Future Research Directions

Psychological well-being is a broad concept covering multiple distinct components. Each component of psychological well-being itself is associated with a range of factors. Therefore, PA alone may not be sufficient to substantially change psychological well-being in older adults. Future research is suggested to develop interventions combining PA and other potential factors such as social participation and cognition-enhancing activities and examine their effects on different components of psychological well-being.

A challenge identified in the existing literature is the inconsistency regarding the conceptualization and assessment of psychological well-being. The relationship between PA and psychological well-being may vary based on the component of psychological well-being and the measurement tools used to assess it. To fully reflect the relationship, future research is suggested to include measurement covering all three dimensions of psychological well-being, i.e., mental ill-being, hedonic well-being, and eudaimonic well-being.

The research on PA and positive psychological well-being is still in its infancy. The mechanisms linking possible relationships between PA and positive psychological well-being remain largely unexplored and might be a fruitful direction for future research. Currently, there is no single theory that can well explain the relationship between PA and psychological well-being in older adults. Several theories may be promising in advancing our understanding, such as the Activity Theory (Longino Jr & Kart, 1982), Self-Determination Theory (Ryan & Deci, 2000), and Social Cognitive Theory (Bandura, 1977). Future research could test these theories in the relationship between PA and psychological well-being and advance our theoretical understanding of how PA and psychological well-being interact in older adults.

Appendices

Appendix A

The 7-Item Scale of Purpose in Life

Item 1 – I enjoy making plans for the future and working to make them a reality.

Item 2 – My daily activities often seem trivial and unimportant to me.

Item 3 – I am an active person in carrying out the plans I set for myself.

Item 4 – I don't have a good sense of what it is I'm trying to accomplish in life.

Item 5 – I sometimes feel as if I've done all there is to do in life.

Item 6 – I live life one day at a time and don’t really think about the future.

Item 7 – I have a sense of direction and purpose in my life.

Appendix B

Satisfaction With Life Scale

Item 1 – In most ways my life is close to my ideal.

Item 2 – The conditions of my life are excellent.

Item 3 – I am satisfied with my life.

Item 4 – So far I have gotten the important things I want in life.

Item 5 – If I could live my life over, I would change almost nothing.

Appendix C

Subjective Happiness Scale

Item 1 – In general, I consider myself a very happy person.

Item 2 – Compared to most of my peers, I consider myself more happy.

Item 3 – I am generally very happy. I enjoy life regardless of what is going on, getting the most out of everything.

Item 4 – I am generally not very happy. Although I am not depressed, I never seem as happy as I might be.

Appendix D

The 18-item Psychological Well-Being Scale

Item 1 – I like most parts of my personality.

Item 2 – When I look at the story of my life, I am pleased with how things have turned out so far.

Item 3 – Some people wander aimlessly through life, but I am not one of them.

Item 4 – The demands of everyday life often get me down.

Item 5 – In many ways I feel disappointed about my achievements in life.

Item 6 – Maintaining close relationships has been difficult and frustrating for me.

Item 7 – I live life one day at a time and don't really think about the future.

Item 8 – In general, I feel I am in charge of the situation in which I live.

Item 9 – I am good at managing the responsibilities of daily life.

Item 10 – I sometimes feel as if I've done all there is to do in life.

Item 11 – For me, life has been a continuous process of learning, changing, and growth.

Item 12 – I think it is important to have new experiences that challenge how I think about myself and the world.

Item 13 – People would describe me as a giving person, willing to share my time with others.

Item 14 – I gave up trying to make big improvements or changes in my life a long time ago.

Item 15 – I tend to be influenced by people with strong opinions.

Item 16 – I have not experienced many warm and trusting relationships with others.

Item 17 – I have confidence in my own opinions, even if they are different from the way most other people think.

Item 18 – I judge myself by what I think is important, not by the values of what others think is important.

Appendix E

Centre for Epidemiological Studies Depression Inventory

Item 1 – I was bothered by things that usually don't bother me.

Item 2 – I had trouble keeping my mind on what I was doing.

Item 3 – I felt depressed.

Item 4 – I felt that everything I did was an effort.

Item 5 – I felt hopeful about the future.

Item 6 – I felt fearful.

Item 7 – My sleep was restless.

Item 8 – I was happy.

Item 9 – I felt lonely.

Item 10 – I could not "get going."

Bibliography

Andersen, L. B., Schnohr, P., Schroll, M., & Hein, H. O. (2000). All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. *Archives of internal medicine, 160*(11), 1621-1628.

Anderson, M., & Perrin, A. (2017). Technology use among seniors. Washington, DC: Pew Research Center for Internet & Technology.

Andresen, E. M., Malmgren, J. A., Carter, W. B., & Patrick, D. L. (1994). Screening for depression in well older adults: Evaluation of a short form of the CES-D. *American journal of preventive medicine, 10*(2), 77-84.

Andrew, M. K., Fisk, J. D., & Rockwood, K. (2012). Psychological well-being in relation to frailty: a frailty identity crisis? *International psychogeriatrics, 24*(8), 1347-1353.

Angevaren, M., Aufdemkampe, G., Verhaar, H., Aleman, A., & Vanhees, L. (2008). Physical activity and enhanced fitness to improve cognitive function in older people without known cognitive impairment. *Cochrane database of systematic reviews*(2), 1-61.

Angner, E., Ghandhi, J., Purvis, K. W., Amante, D., & Allison, J. (2013). Daily functioning, health status, and happiness in older adults. *Journal of happiness studies, 14*(5), 1563-1574.

Arbuckle, J. L., Marcoulides, G. A., & Schumacker, R. E. (1996). Full information estimation in the presence of incomplete data *Advanced structural equation modeling: Issues and techniques* (pp. 243-277). Mahwah, NJ: Lawrence Erlbaum.

Ashford, S., Edmunds, J., & French, D. P. (2010). What is the best way to change self‐efficacy to promote lifestyle and recreational physical activity? A systematic review with meta‐analysis. *British journal of health psychology, 15*(2), 265-288.

Babyak, M., Blumenthal, J. A., Herman, S., Khatri, P., Doraiswamy, M., Moore, K., . . . Krishnan, K. R. (2000). Exercise treatment for major depression: maintenance of therapeutic benefit at 10 months. *Psychosomatic medicine, 62*(5), 633-638.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review, 84*(2), 191-215.

Bandura, A. (1991). Social cognitive theory of self-regulation. *Organizational behavior and human decision processes, 50*(2), 248-287.

Barreto, P. (2014). Direct and indirect relationships between physical activity and happiness levels among older adults: a cross-sectional study. *Aging & mental health, 18*(7), 861-868.

Batty, G. D. (2002). Physical activity and coronary heart disease in older adults: a systematic review of epidemiological studies. *The European Journal of Public Health, 12*(3), 171-176.

Beauchamp, M. R., Carron, A. V., McCutcheon, S., & Harper, O. (2007). Older adults' preferences for exercising alone versus in groups: considering contextual congruence. *Annals of behavioral Medicine, 33*(2), 200-206.

Berg, A. I., Hoffman, L., Hassing, L. B., McClearn, G. E., & Johansson, B. (2009). What matters, and what matters most, for change in life satisfaction in the oldest-old? A study over 6 years among individuals 80+. *Aging and Mental Health, 13*(2), 191-201.

Blazer, D. G. (2003). Depression in late life: review and commentary. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 58*(3), M249-M265.

Blazer, D. G. (2006). Successful aging. *The American Journal of Geriatric Psychiatry, 14*(1), 2-5.

Blumenthal, J. A., Babyak, M. A., Moore, K. A., Craighead, W. E., Herman, S., Khatri, P., . . . Appelbaum, M. (1999). Effects of exercise training on older patients with major depression. *Archives of internal medicine, 159*(19), 2349-2356.

Bollen, K. A. (1989). A new incremental fit index for general structural equation models. *Sociological Methods & Research, 17*(3), 303-316.

Borson, S., Scanlan, J. M., Chen, P., & Ganguli, M. (2003). The Mini‐Cog as a screen for dementia: validation in a population‐based sample. *Journal of the American Geriatrics Society, 51*(10), 1451-1454.

Boyle, P. A., Barnes, L. L., Buchman, A. S., & Bennett, D. A. (2009). Purpose in life is associated with mortality among community-dwelling older persons. *Psychosomatic medicine, 71*(5), 574.

Boyle, P. A., Buchman, A. S., Barnes, L. L., & Bennett, D. A. (2010). Effect of a purpose in life on risk of incident Alzheimer disease and mild cognitive impairment in community-dwelling older persons. *Archives of general psychiatry, 67*(3), 304-310.

Brassai, L., Piko, B. F., & Steger, M. F. (2015). A reason to stay healthy: The role of meaning in life in relation to physical activity and healthy eating among adolescents. *Journal of Health Psychology, 20*(5), 473-482.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology, 3*(2), 77-101.

Bravata, D. M., Smith-Spangler, C., Sundaram, V., Gienger, A. L., Lin, N., Lewis, R., . . . Sirard, J. R. (2007). Using pedometers to increase physical activity and improve health: a systematic review. *Jama, 298*(19), 2296-2304.

Breitbart, W., Poppito, S., Rosenfeld, B., Vickers, A. J., Li, Y., Abbey, J., . . . Sjoberg, D. (2012). Pilot randomized controlled trial of individual meaning-centered psychotherapy for patients with advanced cancer. *Journal of clinical oncology, 30*(12), 1304-1309.

Brenes, G. A., Williamson, J. D., Messier, S. P., Rejeski, W. J., Pahor, M., Ip, E., & Penninx, B. W. (2007). Treatment of minor depression in older adults: a pilot study comparing sertraline and exercise. *Aging and Mental Health, 11*(1), 61-68.

Brown, T. A. (2015). *Confirmatory factor analysis for applied research*: Guilford publications.

Buedo Guirado, C., Rubio Rubio, L., Dumitrache, C. G., & Romero Coronado, J. (2020). Active Aging Program in Nursing Homes: Effects on Psychological Well-being and Life Satisfaction. *Psychosocial Intervention, 29*(1), 49-57.

Butler, R. N. (1997). Population aging and health. *Bmj, 315*(7115), 1082-1084.

Byers, A. L., Yaffe, K., Covinsky, K. E., Friedman, M. B., & Bruce, M. L. (2010). High occurrence of mood and anxiety disorders among older adults: The National Comorbidity Survey Replication. *Archives of general psychiatry, 67*(5), 489-496.

Cadmus-Bertram, L., Marcus, B. H., Patterson, R. E., Parker, B. A., & Morey, B. L. (2015). Randomized trial of a Fitbit-based physical activity intervention for women. *American journal of preventive medicine, 49*(3), 414-418.

Carlson, S. A., Densmore, D., Fulton, J. E., Yore, M. M., & Kohl, H. W. (2009). Differences in physical activity prevalence and trends from 3 US surveillance systems: NHIS, NHANES, and BRFSS. *Journal of Physical Activity and Health, 6*(s1), S18-S27.

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public health reports, 100*(2), 126-131.

Centers for Disease Control and Prevention. (2008). Preventing obesity and chronic diseases through good nutrition and physical activity. Hyattsville, MD: US Department of Health and Human Services.

Centers for Disease Control and Prevention. (2012). National Health and Nutrition Examination Survey Data. Hyattsville, MD: US Department of Health and Human Services.

Centers for Medicare and Medicaid Services. (2015). Your guide to choosing a nursing home or other long-term care. Hyattsville, MD: US Department of Health and Human Services.

Chen, D. S., Betz, J., Yaffe, K., Ayonayon, H. N., Kritchevsky, S., Martin, K. R., . . . Xue, Q.-L. (2015). Association of hearing impairment with declines in physical functioning and the

risk of disability in older adults. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences, 70*(5), 654-661.

Chi, I., Jordan‐Marsh, M., Guo, M., Xie, B., & Bai, Z. (2013). Tai chi and reduction of depressive symptoms for older adults: A meta‐analysis of randomized trials. *Geriatrics & gerontology international, 13*(1), 3-12.

Chida, Y., & Steptoe, A. (2008). Positive psychological well-being and mortality: a quantitative review of prospective observational studies. *Psychosomatic medicine, 70*(7), 741-756.

Chodzko-Zajko, W. J., Proctor, D. N., Singh, M. A. F., Minson, C. T., Nigg, C. R., Salem, G. J., & Skinner, J. S. (2009). Exercise and physical activity for older adults. *Medicine & science in sports & exercise, 41*(7), 1510-1530.

Choi, S., McDonough, I. M., Kim, M., & Kim, G. (2018). The association between the number of chronic health conditions and advance care planning varies by race/ethnicity. *Aging & mental health, 24*(3), 453-463.

Clarke, P. J., Marshall, V. W., Ryff, C. D., & Wheaton, B. (2001). Measuring psychological well-being in the Canadian study of health and aging. *International psychogeriatrics, 13*(S1), 79-90.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. New York, NY: Routledge Academic

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: a meta-analytic study. *Psychological science, 14*(2), 125-130.

Conn, V. S., Valentine, J. C., & Cooper, H. M. (2002). Interventions to increase physical activity among aging adults: a meta-analysis. *Annals of behavioral Medicine, 24*(3), 190-200.

Conradsson, M., Littbrand, H., Lindelöf, N., Gustafson, Y., & Rosendahl, E. (2010). Effects of a high-intensity functional exercise programme on depressive symptoms and psychological well-being among older people living in residential care facilities: a cluster-randomized controlled trial. *Aging & mental health, 14*(5), 565-576.

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., . . . Sallis, J. F. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & science in sports & exercise, 35*(8), 1381-1395.

Crosswell, A. D., Suresh, M., Puterman, E., Gruenewald, T. L., Lee, J., & Epel, E. S. (2018). Advancing Research on Psychosocial Stress and Aging with the Health and Retirement Study: Looking Back to Launch the Field Forward. *The Journals of Gerontology: Series B, 75*(5), 970-980.

Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychological methods, 1*(1), 16-29.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly, 13*(3), 319-340.

de Rezende, L. F. M., Rey-López, J. P., Matsudo, V. K. R., & do Carmo Luiz, O. (2014). Sedentary behavior and health outcomes among older adults: a systematic review. *BMC public health, 14*(1), 1-9.

Delacre, M., Lakens, D., & Leys, C. (2017). Why psychologists should by default use Welch's t-test instead of Student's t-test. *International Review of Social Psychology, 30*(1), 92-101.

Delextrat, A. A., Warner, S., Graham, S., & Neupert, E. (2016). An 8-week exercise intervention based on zumba improves aerobic fitness and psychological well-being in healthy women. *Journal of Physical Activity and Health, 13*(2), 131-139.

DeSalvo, K. B., Bloser, N., Reynolds, K., He, J., & Muntner, P. (2006). Mortality prediction with a single general self‐rated health question: A meta‐analysis. *Journal of general internal medicine, 21*(3), 267-275.

Diener, E. (1984). Subjective well-being. *Psychological bulletin, 95*(3), 542.

Diener, E., & Chan, M. Y. (2011). Happy people live longer: Subjective well‐being contributes to health and longevity. *Applied Psychology: Health and Well‐Being, 3*(1), 1-43.

Diener, E., Emmons, R. A., Larsen, R. J., & Griffin, S. (1985). The satisfaction with life scale. *Journal of personality assessment, 49*(1), 71-75.

Diener, E., Sandvik, E., & Pavot, W. (2009). Happiness is the frequency, not the intensity, of positive versus negative affect *Assessing well-being* (pp. 213-231). New York, NY: Springer.

Duckham, R. L., Tait, J. L., Nowson, C. A., Sanders, K. M., Taaffe, D. R., Hill, K. D., & Daly, R. M. (2018). Strategies and challenges associated with recruiting retirement village communities and residents into a group exercise intervention. *BMC Med Res Methodol, 18*(1), 1-10.

Fisher, K. J., & Li, F. (2004). A community-based walking trial to improve neighborhood quality of life in older adults: a multilevel analysis. *Annals of behavioral Medicine, 28*(3), 186-194.

Fiske, A., Wetherell, J. L., & Gatz, M. (2009). Depression in older adults. *Annual review of clinical psychology, 5*, 363-389.

Forte, R., Boreham, C. A., Leite, J. C., De Vito, G., Brennan, L., Gibney, E. R., & Pesce, C. (2013). Enhancing cognitive functioning in the elderly: multicomponent vs resistance training. *Clinical interventions in aging, 8*, 19-27.

Fox, K. R., Stathi, A., McKenna, J., & Davis, M. G. (2007). Physical activity and mental well-being in older people participating in the Better Ageing Project. *European journal of applied physiology, 100*(5), 591-602.

Freiberger, E., Kemmler, W., Siegrist, M., & Sieber, C. (2016). Frailty and exercise interventions. *Zeitschrift für gerontologie und geriatrie, 49*(7), 606-611.

Friedman, E. M., Hayney, M., Love, G. D., Singer, B. H., & Ryff, C. D. (2007). Plasma interleukin-6 and soluble IL-6 receptors are associated with psychological well-being in aging women. *Health Psychology, 26*(3), 305-313.

Gunnell, K. E., Mack, D. E., Wilson, P. M., & Adachi, J. (2011). Psychological needs as mediators? The relationship between leisure-time physical activity and well being in people diagnosed with osteoporosis. *Research quarterly for exercise and sport, 82*(4), 794-798.

Gwozdz, W., & Sousa-Poza, A. (2010). Ageing, health and life satisfaction of the oldest old: An analysis for Germany. *Social Indicators Research, 97*(3), 397-417.

Hagen, S. (2013). Rising demand for long-term services and supports for elderly people. Washington, DC: Congressional Budget Office.

Hamer, M., Lavoie, K. L., & Bacon, S. L. (2014). Taking up physical activity in later life and healthy ageing: the English longitudinal study of ageing. *Br J Sports Med, 48*(3), 239-243.

Haskell, W. L., Lee, I.-M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., . . . Bauman, A. (2007). Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation, 116*(9), 1423-1434.

Heath, G. W., Parra, D. C., Sarmiento, O. L., Andersen, L. B., Owen, N., Goenka, S., . . . Group, L. P. A. S. W. (2012). Evidence-based intervention in physical activity: lessons from around the world. *The Lancet, 380*(9838), 272-281.

Holahan, C. K., Holahan, C. J., Chen, Y. T., & Li, X. (2019). Leisure-time physical activity and affective experience in middle-aged and older women. *Journal of women & aging, 1*(9), 1-12.

Holahan, C. K., Holahan, C. J., & Suzuki, R. (2008). Purposiveness, physical activity, and perceived health in cardiac patients. *Disability and rehabilitation, 30*(23), 1772-1778.

Holahan, C. K., Holahan, C. J., Velasquez, K. E., Jung, S., North, R. J., & Pahl, S. A. (2011). Purposiveness and leisure-time physical activity in women in early midlife. *Women & health, 51*(7), 661-675.

Holahan, C. K., & Suzuki, R. (2006). Motivational factors in health promoting behavior in later aging. *Activities, Adaptation & Aging, 30*(1), 47-60.

Homan, K. J. (2016). Self-compassion and psychological well-being in older adults. *Journal of Adult Development, 23*(2), 111-119.

Homan, K. J., & Boyatzis, C. J. (2010). Religiosity, sense of meaning, and health behavior in older adults. *The International Journal for the Psychology of Religion, 20*(3), 173-186.

Hooker, S. A., & Masters, K. S. (2016). Purpose in life is associated with physical activity measured by accelerometer. *Journal of Health Psychology, 21*(6), 962-971.

Huang, G., Gibson, C. A., Tran, Z. V., & Osness, W. H. (2005). Controlled endurance exercise training and VO2max changes in older adults: a meta‐analysis. *Preventive cardiology, 8*(4), 217-225.

Hung, W. W., Ross, J. S., Boockvar, K. S., & Siu, A. L. (2011). Recent trends in chronic disease, impairment and disability among older adults in the United States. *BMC geriatrics, 11*(1), 2-12.

Irwin, M., Artin, K. H., & Oxman, M. N. (1999). Screening for depression in the older adult: criterion validity of the 10-item Center for Epidemiological Studies Depression Scale (CES-D). *Archives of internal medicine, 159*(15), 1701-1704.

Jacobs, T. L., Epel, E. S., Lin, J., Blackburn, E. H., Wolkowitz, O. M., Bridwell, D. A., . . . MacLean, K. A. (2011). Intensive meditation training, immune cell telomerase activity, and psychological mediators. *Psychoneuroendocrinology, 36*(5), 664-681.

Ju, H. (2017). The relationship between physical activity, meaning in life, and subjective vitality in community-dwelling older adults. *Archives of gerontology and geriatrics, 73*, 120-124.

Keadle, S. K., McKinnon, R., Graubard, B. I., & Troiano, R. P. (2016). Prevalence and trends in physical activity among older adults in the United States: a comparison across three national surveys. *Preventive medicine, 89*, 37-43.

Kearney, M. W. (2017). *The SAGE encyclopedia of communication research methods*. Thousand Oaks, CA: SAGE Publications, Inc.

Kenny, D. A. (1975). Cross-lagged panel correlation: A test for spuriousness. *Psychological bulletin, 82*(6), 887-903.

Kerr, J., Marshall, S. J., Patterson, R. E., Marinac, C. R., Natarajan, L., Rosenberg, D., . . . Crist, K. (2013). Objectively measured physical activity is related to cognitive function in older adults. *Journal of the American Geriatrics Society, 61*(11), 1927-1931.

Kerr, J., Rosenberg, D., Millstein, R. A., Bolling, K., Crist, K., Takemoto, M., . . . Castro-Sweet, C. (2018). Cluster randomized controlled trial of a multilevel physical activity intervention for older adults. *international journal of behavioral nutrition and physical activity, 15*(1), 2-9.

Keyes, C. L. (2002). The mental health continuum: From languishing to flourishing in life. *Journal of health and social behavior, 43*, 207-222.

Keyes, C. L. (2007). Promoting and protecting mental health as flourishing: A complementary strategy for improving national mental health. *American psychologist, 62*(2), 95-108.

Kim, E. S., Sun, J. K., Park, N., & Peterson, C. (2013). Purpose in life and reduced incidence of stroke in older adults:'The Health and Retirement Study'. *Journal of psychosomatic research, 74*(5), 427-432.

Kim, J., Chun, S., Heo, J., Lee, S., & Han, A. (2016). Contribution of leisure-time physical activity on psychological benefits among elderly immigrants. *Applied research in quality of life, 11*(2), 461-470.

Kim, J., Lee, S., Chun, S., Han, A., & Heo, J. (2017). The effects of leisure-time physical activity for optimism, life satisfaction, psychological well-being, and positive affect among older adults with loneliness. *Annals of leisure research, 20*(4), 406-415.

King, A. C., Rejeski, W. J., & Buchner, D. M. (1998). Physical activity interventions targeting older adults: A critical review and recommendations. *American journal of preventive medicine, 15*(4), 316-333.

Kline, R. B. (2015). *Principles and practice of structural equation modeling*. New York City, NY: Guilford Publications.

Kluge, M. A. (2015). Physical Activity Programmes in Residential Care Settings *Physical Activity and Sport in Later Life* (pp. 81-91). New York, NY: Springer.

Koizumi, D., Rogers, N. L., Rogers, M. E., Islam, M. M., Kusunoki, M., & Takeshima, N. (2009). Efficacy of an accelerometer-guided physical activity intervention in community-dwelling older women. *Journal of Physical Activity and Health, 6*(4), 467-474.

Koopmans, T. A., Geleijnse, J. M., Zitman, F. G., & Giltay, E. J. (2010). Effects of happiness on all-cause mortality during 15 years of follow-up: The Arnhem Elderly Study. *Journal of happiness studies, 11*(1), 113-124.

Ku, P.-W., Fox, K. R., & Chen, L.-J. (2016). Leisure-time physical activity, sedentary behaviors and subjective well-being in older adults: An eight-year longitudinal research. *Social Indicators Research, 127*(3), 1349-1361.

Lee, I.-M., Shiroma, E. J., Kamada, M., Bassett, D. R., Matthews, C. E., & Buring, J. E. (2019). Association of step volume and intensity with all-cause mortality in older women. *JAMA internal medicine, 179*(8), 1105-1112.

Leonhardt, C., Lehr, D., Chenot, J.-F., Keller, S., Luckmann, J., Basler, H.-D., . . . Hildebrandt, J. (2009). Are fear-avoidance beliefs in low back pain patients a risk factor for low physical activity or vice versa? A cross-lagged panel analysis. *GMS Psycho-Social-Medicine, 6*, 1-12.

Lera-López, F., Ollo-López, A., & Sánchez-Santos, J. M. (2017). How does physical activity make you feel better? The mediational role of perceived health. *Applied research in quality of life, 12*(3), 511-531.

Li, F., Duncan, T. E., Duncan, S. C., McAuley, E., Chaumeton, N. R., & Harmer, P. (2001). Enhancing the psychological well-being of elderly individuals through Tai Chi exercise: a latent growth curve analysis. *Structural Equation Modeling, 8*(1), 53-83.

Lincoln, A. K., Shepherd, A., Johnson, P. L., & Castaneda-Sceppa, C. (2011). The impact of resistance exercise training on the mental health of older Puerto Rican adults with type 2 diabetes. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 66*(5), 567-570.

Longino Jr, C. F., & Kart, C. S. (1982). Explicating activity theory: A formal replication. *Journal of Gerontology, 37*(6), 713-722.

Loprinzi, P. D. (2013). Objectively measured light and moderate-to-vigorous physical activity is associated with lower depression levels among older US adults. *Aging & mental health, 17*(7), 801-805.

Lunney, J. R., Lynn, J., Foley, D. J., Lipson, S., & Guralnik, J. M. (2003). Patterns of functional decline at the end of life. *Jama, 289*(18), 2387-2392.

Lyons, E. J., Lewis, Z. H., Mayrsohn, B. G., & Rowland, J. L. (2014). Behavior change techniques implemented in electronic lifestyle activity monitors: a systematic content analysis. *Journal of medical Internet research, 16*(8), e192.

Lyubomirsky, S., & Lepper, H. S. (1999). A measure of subjective happiness: Preliminary reliability and construct validation. *Social Indicators Research, 46*(2), 137-155.

Mack, D. E., Wilson, P. M., Gunnell, K. E., Gilchrist, J. D., Kowalski, K. C., & Crocker, P. R. (2012). Health‐enhancing physical activity: associations with markers of well‐being. *Applied Psychology: Health and Well‐Being, 4*(2), 127-150.

Maki, Y., Ura, C., Yamaguchi, T., Murai, T., Isahai, M., Kaiho, A., . . . Sugiyama, M. (2012). Effects of intervention using a community‐based walking program for prevention of mental decline: a randomized controlled trial. *Journal of the American Geriatrics Society, 60*(3), 505-510.

Mammen, G., & Faulkner, G. (2013). Physical activity and the prevention of depression: a systematic review of prospective studies. *American journal of preventive medicine, 45*(5), 649-657.

McAuley, E., Blissmer, B., Marquez, D. X., Jerome, G. J., Kramer, A. F., & Katula, J. (2000). Social relations, physical activity, and well-being in older adults. *Preventive medicine, 31*(5), 608-617.

McAuley, E., & Rudolph, D. (1995). Physical activity, aging, and psychological well-being. *Journal of Aging and Physical Activity, 3*(1), 67-96.

McDowell, I. (2010). Measures of self-perceived well-being. *Journal of psychosomatic research, 69*(1), 69-79.

McGregor, I., & Little, B. R. (1998). Personal projects, happiness, and meaning: on doing well and being yourself. *Journal of personality and social psychology, 74*(2), 494-521.

McMahan, E. A., & Estes, D. (2011). Hedonic versus eudaimonic conceptions of well-being: Evidence of differential associations with self-reported well-being. *Social Indicators Research, 103*(1), 93-108.

Meeks, T. W., Vahia, I. V., Lavretsky, H., Kulkarni, G., & Jeste, D. V. (2011). A tune in "a minor" can "b major": a review of epidemiology, illness course, and public health implications of subthreshold depression in older adults. *Journal of affective disorders, 129*(1-3), 126-142.

Mercer, K., Giangregorio, L., Schneider, E., Chilana, P., Li, M., & Grindrod, K. (2016). Acceptance of commercially available wearable activity trackers among adults aged over 50 and with chronic illness: a mixed-methods evaluation. *JMIR mHealth and uHealth, 4*(1), e7.

Michie, S., Abraham, C., Whittington, C., McAteer, J., & Gupta, S. (2009). Effective techniques in healthy eating and physical activity interventions: a meta-regression. *Health Psychology, 28*(6), 690-701.

Michie, S., Ashford, S., Sniehotta, F. F., Dombrowski, S. U., Bishop, A., & French, D. P. (2011). A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: the CALO-RE taxonomy. *Psychology & health, 26*(11), 1479-1498.

Milanović, Z., Pantelić, S., Trajković, N., Sporiš, G., Kostić, R., & James, N. (2013). Age-related decrease in physical activity and functional fitness among elderly men and women. *Clinical interventions in aging, 8*, 549-556.

Moore, K. A., Babyak, M. A., Wood, C. E., Napolitano, M. A., Khatri, P., Craighead, W. E., . . . Blumenthal, J. A. (1999). The association between physical activity and depression in older depressed adults. *Journal of Aging and Physical Activity, 7*(1), 55-61.

Musich, S., Wang, S. S., Kraemer, S., Hawkins, K., & Wicker, E. (2018). Purpose in life and positive health outcomes among older adults. *Population health management, 21*(2), 139-147.

Muthén, L., & Muthén, B. (2019). *The comprehensive modelling program for applied researchers: user's guide*. Los Angeles, CA: Muthén & Muthén.

Netz, Y., Wu, M.-J., Becker, B. J., & Tenenbaum, G. (2005). Physical activity and psychological well-being in advanced age: a meta-analysis of intervention studies. *Psychology and aging, 20*(2), 272-284.

Nguyen, N. H., Hadgraft, N. T., Moore, M. M., Rosenberg, D. E., Lynch, C., Reeves, M. M., & Lynch, B. M. (2017). A qualitative evaluation of breast cancer survivors' acceptance of and preferences for consumer wearable technology activity trackers. *Supportive Care in Cancer, 25*(11), 3375-3384.

Nikander, R., Sievänen, H., Heinonen, A., Daly, R. M., Uusi-Rasi, K., & Kannus, P. (2010). Targeted exercise against osteoporosis: a systematic review and meta-analysis for optimising bone strength throughout life. *BMC medicine, 8*(1), 47.

Niven, A. G., & Markland, D. (2016). Using self-determination theory to understand motivation for walking: Instrument development and model testing using Bayesian structural equation modelling. *Psychology of Sport and Exercise, 23*, 90-100.

O'Brien, N., McDonald, S., Araújo-Soares, V., Lara, J., Errington, L., Godfrey, A., . . . White, M. (2015). The features of interventions associated with long-term effectiveness of physical activity interventions in adults aged 55–70 years: a systematic review and meta-analysis. *Health psychology review, 9*(4), 417-433.

Oliveira, J. S., Sherrington, C., Amorim, A. B., Dario, A. B., & Tiedemann, A. (2017). What is the effect of health coaching on physical activity participation in people aged 60 years and over? A systematic review of randomised controlled trials. *British journal of sports medicine, 51*(19), 1425-1432.

Ortman, J. M., Velkoff, V. A., & Hogan, H. (2014). *An aging nation: the older population in the United States*. Suitland, MD: United States Census Bureau, Economics and Statistics Administration, US Department of Commerce.

Parker, S. J., Strath, S. J., & Swartz, A. M. (2008). Physical activity measurement in older adults: relationships with mental health. *Journal of Aging and Physical Activity, 16*(4), 369-380.

Patel, A. V., Hildebrand, J. S., Leach, C. R., Campbell, P. T., Doyle, C., Shuval, K., . . . Gapstur, S. M. (2018). Walking in relation to mortality in a large prospective cohort of older US adults. *American journal of preventive medicine, 54*(1), 10-19.

Patel, M. S., Asch, D. A., & Volpp, K. G. (2015). Wearable devices as facilitators, not drivers, of health behavior change. *Jama, 313*(5), 459-460.

Paul, S. S., Tiedemann, A., Hassett, L. M., Ramsay, E., Kirkham, C., Chagpar, S., & Sherrington, C. (2015). Validity of the Fitbit activity tracker for measuring steps in community-dwelling older adults. *BMJ open sport & exercise medicine, 1*(1), 1-5.

Paulo, T. R., Tribess, S., Sasaki, J. E., Meneguci, J., Martins, C. A., Freitas, I. F., . . . Virtuoso, J. S. (2016). A cross-sectional study of the relationship of physical activity with depression

and cognitive deficit in older adults. *Journal of Aging and Physical Activity, 24*(2), 311-321.

Pavot, W., Diener, E., Colvin, C. R., & Sandvik, E. (1991). Further validation of the Satisfaction with Life Scale: Evidence for the cross-method convergence of well-being measures. *Journal of personality assessment, 57*(1), 149-161.

Peitsch, L., Tyas, S. L., Menec, V. H., & John, P. D. S. (2016). General life satisfaction predicts dementia in community living older adults: a prospective cohort study. *International psychogeriatrics, 28*(7), 1101-1109.

Pinquart, M. (2002). Creating and maintaining purpose in life in old age: A meta-analysis. *Ageing international, 27*(2), 90-114.

Podsiadlo, D., & Richardson, S. (1991). The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society, 39*(2), 142-148.

Pollard, J. M., Taylor, W. C., & Smith, D. P. (2001). Patterns and correlates of physical activity among older adults residing independently in retirement communities. *Activities, Adaptation & Aging, 24*(4), 1-17.

Radloff, L. S. (1977). The CES-D scale: A self-report depression scale for research in the general population. *Applied psychological measurement, 1*(3), 385-401.

Rector, J. L., Christ, S. L., & Friedman, E. M. (2019). Well-being and long-term physical activity participation in midlife adults: A latent class analysis. *Annals of behavioral Medicine, 53*(1), 53-64.

Rejeski, W. J., & Mihalko, S. L. (2001). Physical activity and quality of life in older adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 56*(suppl_2), 23-35.

Rhyner, K. T., & Watts, A. (2016). Exercise and depressive symptoms in older adults: A systematic meta-analytic review. *Journal of Aging and Physical Activity, 24*(2), 234-246.

Roddy, E., Zhang, W., & Doherty, M. (2005). Aerobic walking or strengthening exercise for osteoarthritis of the knee? A systematic review. *Annals of the rheumatic diseases, 64*(4), 544-548.

Roepke, A. M., Jayawickreme, E., & Riffle, O. M. (2014). Meaning and health: A systematic review. *Applied research in quality of life, 9*(4), 1055-1079.

Rosenberg, D., Kadokura, E. A., Bouldin, E. D., Miyawaki, C. E., Higano, C. S., & Hartzler, A. L. (2016). *Acceptability of Fitbit for physical activity tracking within clinical care among men with prostate cancer.* Paper presented at the AMIA Annual Symposium Proceedings.

Ruini, C., & Fava, G. A. (2012). Role of well‐being therapy in achieving a balanced and individualized path to optimal functioning. *Clinical psychology & psychotherapy, 19*(4), 291-304.

Rush, C. L., Hooker, S. A., Ross, K. M., Frers, A. K., Peters, J. C., & Masters, K. S. (2019). Meaning in life is mediated by self-efficacy in the prediction of physical activity. *Journal of Health Psychology, 1*(1), 1-5.

Ruuskanen, J., & Ruoppila, I. (1995). Physical activity and psychological well-being among people aged 65 to 84 years. *Age and ageing, 24*(4), 292-296.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist, 55*(1), 68-78.

Ryan, R. M., & Deci, E. L. (2001). On happiness and human potentials: A review of research on hedonic and eudaimonic well-being. *Annual review of psychology, 52*(1), 141-166.

Ryan, R. M., & Frederick, C. (1997). On energy, personality, and health: Subjective vitality as a dynamic reflection of well‐being. *Journal of personality, 65*(3), 529-565.

Ryan, R. M., Huta, V., & Deci, E. L. (2008). Living well: A self-determination theory perspective on eudaimonia. *Journal of happiness studies, 9*(1), 139-170.

Ryff, C. D. (1989). Happiness is everything, or is it? Explorations on the meaning of psychological well-being. *Journal of personality and social psychology, 57*(6), 10691081.

Ryff, C. D. (2014). Psychological well-being revisited: Advances in the science and practice of eudaimonia. *Psychotherapy and psychosomatics, 83*(1), 10-28.

Ryff, C. D., & Boylan, J. M. (2016). Linking happiness to health: Comparisons between hedonic and eudaimonic well-being *Handbook of research methods and applications in happiness and quality of life*. Northampton, MA: Edward Elgar Publishing.

Ryff, C. D., & Keyes, C. L. M. (1995). The structure of psychological well-being revisited. *Journal of personality and social psychology, 69*(4), 719-727.

Ryff, C. D., & Singer, B. (1998). The contours of positive human health. *Psychological inquiry, 9*(1), 1-28.

Ryff, C. D., & Singer, B. H. (2008). Know thyself and become what you are: A eudaimonic approach to psychological well-being. *Journal of happiness studies, 9*(1), 13-39.

Sallis, J. F., Owen, N., & Fisher, E. (2015). Ecological models of health behavior. *Health behavior: Theory, research, and practice, 5*, 43-64.

Salmon, J., Owen, N., Crawford, D., Bauman, A., & Sallis, J. F. (2003). Physical activity and sedentary behavior: a population-based study of barriers, enjoyment, and preference. *Health Psychology, 22*(2), 178-188.

Schimmack, U., Diener, E., & Oishi, S. (2002). Life‐satisfaction is a momentary judgment and a stable personality characteristic: The use of chronically accessible and stable sources. *Journal of personality, 70*(3), 345-384.

Seligman, M., & Csikszentmihalyi, M. (2000). Positive psychology. An introduction. *The American psychologist, 55*(1), 5-14.

Sherrington, C., Tiedemann, A., Fairhall, N., Close, J. C., & Lord, S. R. (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. *New South Wales public health bulletin, 22*(4), 78-83.

Smith, J., Borchelt, M., Maier, H., & Jopp, D. (2002). Health and well–being in the young old and oldest old. *Journal of Social Issues, 58*(4), 715-732.

Snowden, M., Dhingra, S. S., Keyes, C. L., & Anderson, L. A. (2010). Changes in mental well-being in the transition to late life: findings from MIDUS I and II. *American journal of public health, 100*(12), 2385-2388.

Sonnega, A., Faul, J. D., Ofstedal, M. B., Langa, K. M., Phillips, J. W., & Weir, D. R. (2014). Cohort profile: the health and retirement study (HRS). *International journal of epidemiology, 43*(2), 576-585.

Sonnega, A., & Smith, J. (2015). Health and Retirement Study: A longitudinal data resource for psychologists *Encyclopedia of geropsychology* (pp. 1-13). Singapore: Springer.

St. John, P. D., & Montgomery, P. R. (2010). Cognitive impairment and life satisfaction in older adults. *International journal of geriatric psychiatry, 25*(8), 814-821.

Stathokostas, L., & Jones, G. R. (2016). Exercise modality choices one year after intervention in previously inactive older men and women. *Journal of Aging and Physical Activity, 24*(3), 435-443.

Steger, M. F., Frazier, P., Oishi, S., & Kaler, M. (2006). The meaning in life questionnaire: Assessing the presence of and search for meaning in life. *Journal of counseling psychology, 53*(1), 80-93.

Steptoe, A., Deaton, A., & Stone, A. A. (2015). Subjective wellbeing, health, and ageing. *The Lancet, 385*(9968), 640-648.

Stone, A. A., Schwartz, J. E., Broderick, J. E., & Deaton, A. (2010). A snapshot of the age distribution of psychological well-being in the United States. *Proceedings of the National Academy of Sciences, 107*(22), 9985-9990.

Takkinen, S., Suutama, T., & Ruoppila, I. (2001). More meaning by exercising? Physical activity as a predictor of a sense of meaning in life and of self-rated health and functioning in old age. *Journal of Aging and Physical Activity, 9*(2), 128-141.

Thompson, W. G., Kuhle, C. L., Koepp, G. A., McCrady-Spitzer, S. K., & Levine, J. A. (2014). "Go4Life" exercise counseling, accelerometer feedback, and activity levels in older people. *Archives of gerontology and geriatrics, 58*(3), 314-319.

Troiano, R. P., Berrigan, D., Dodd, K. W., Masse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine & science in sports & exercise, 40*(1), 181-188.

Tsang, K. L. V., Wong, P., & Lo, S. K. (2012). Assessing psychosocial well‐being of adolescents: A systematic review of measuring instruments. *Child: care, health and development, 38*(5), 629-646.

Tse, M. M., Tang, S. K., Wan, V. T., & Vong, S. K. (2014). The effectiveness of physical exercise training in pain, mobility, and psychological well-being of older persons living in nursing homes. *Pain Management Nursing, 15*(4), 778-788.

Tudor-Locke, C., Giles-Corti, B., Knuiman, M., & McCormack, G. (2008). Tracking of pedometer-determined physical activity in adults who relocate: results from RESIDE. *international journal of behavioral nutrition and physical activity, 5*(1), 1-8.

U.S. Census Bureau. (2018a). 2018 Population Estimates. from https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

U.S. Census Bureau. (2018b). Older People Projected to Outnumber Children for First Time in U.S. History. from https://www.census.gov/newsroom/press-releases/2018/cb18-41-population-projections.html

Umpierre, D., Ribeiro, P. A., Kramer, C. K., Leitão, C. B., Zucatti, A. T., Azevedo, M. J., . . . Schaan, B. D. (2011). Physical activity advice only or structured exercise training and association with HbA1c levels in type 2 diabetes: a systematic review and meta-analysis. *Jama, 305*(17), 1790-1799.

US Department of Health and Human Services. (2018). *Physical Activity Guidelines for Americans. 2nd ed.* Wasington, DC: US Dept of Health and Human Services.

Van Der Bij, A. K., Laurant, M. G., & Wensing, M. (2002). Effectiveness of physical activity interventions for older adults: a review. *American journal of preventive medicine, 22*(2), 120-133.

Vella-Brodrick, D. A., & Stanley, J. (2013). The significance of transport mobility in predicting well-being. *Transport Policy, 29*, 236-242.

Wang, J. B., Cadmus-Bertram, L. A., Natarajan, L., White, M. M., Madanat, H., Nichols, J. F., . . . Pierce, J. P. (2015). Wearable sensor/device (Fitbit One) and SMS text-messaging

prompts to increase physical activity in overweight and obese adults: a randomized controlled trial. *Telemedicine and e-Health, 21*(10), 782-792.

Wiesmann, U., & Hannich, H.-J. (2011). Salutogenic perspectives on health maintenance. *GeroPsych, 24*(3), 127-135.

Wolitzky‐Taylor, K. B., Castriotta, N., Lenze, E. J., Stanley, M. A., & Craske, M. G. (2010). Anxiety disorders in older adults: a comprehensive review. *Depression and anxiety, 27*(2), 190-211.

World Health Organization. (2004). *Global strategy on diet, physical activity,and health*. Geneva, Switzerland: World Health Organization.

World Health Organization. (2010). *Global recommendations on physical activity for health*. Geneva, Switzerland: World Health Organization.

World Health Organization. (2014). Mental health: a state of well-being. from http://www.who.int/features/factfiles/mental_health/en/

World Health Organization. (2015). *World report on ageing and health*. Geneva, Switzerland: World Health Organization.

Yang, P.-Y., Ho, K.-H., Chen, H.-C., & Chien, M.-Y. (2012). Exercise training improves sleep quality in middle-aged and older adults with sleep problems: a systematic review. *Journal of physiotherapy, 58*(3), 157-163.

Yeung, G. T., & Fung, H. H. (2007). Social support and life satisfaction among Hong Kong Chinese older adults: family first? *European journal of ageing, 4*(4), 219-227.

Yu, R., Tong, C., Ho, F., & Woo, J. (2020). Effects of a Multicomponent Frailty Prevention Program in Prefrail Community-Dwelling Older Persons: A Randomized Controlled Trial. *Journal of the American Medical Directors Association, 21*(2), 294. e291-294. e210.

Zaslavsky, O., Rillamas-Sun, E., Woods, N. F., Cochrane, B. B., Stefanick, M. L., Tindle, H., . . . LaCroix, A. Z. (2014). Association of the selected dimensions of eudaimonic well-being with healthy survival to 85 years of age in older women. *International psychogeriatrics, 26*(12), 2081-2091.

Zebolsky, G. T. (2014). An Introduction to Continuing Care Retirement Communities. from http://us.milliman.com/insight/2014/An-introduction-to-continuing-care-retirement-communities/

Zhang, Z., & Chen, W. (2019a). A Systematic Review of Measures for Psychological Well-Being in Physical Activity Studies and Identification of Critical Issues. *Journal of affective disorders, 25*(1), 473-485.

Zhang, Z., & Chen, W. (2019b). A systematic review of the relationship between physical activity and happiness. *Journal of happiness studies, 20*(4), 1305-1322.

Zubala, A., MacGillivray, S., Frost, H., Kroll, T., Skelton, D. A., Gavine, A., . . . Morris, J. (2017). Promotion of physical activity interventions for community dwelling older adults: a systematic review of reviews. *PloS one, 12*(7), 1-36.