# Physical activity and the oldest-old:

# A comparison of self-report and accelerometer readings

by

Pascal Lambert

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

Department of Community Health Sciences

University of Manitoba

Winnipeg

**Physical activity and the oldest-old: A comparison of self-report and accelerometer readings**

**BY**

Pascal Lambert

**A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of**

**Manitoba in partial fulfillment of the requirement of the degree**

**OF**

**MASTER OF SCIENCE**

**Abstract**

A sample of 100 80+-year old community-dwelling Winnipeggers were studied to 1) determine how compliant they are in wearing an accelerometer; 2) examine the stability of accelerometer data over a three-day period; 3) examine the relationship between accelerometer and self-report measures of activity; and 4) examine the relationship between activity and well-being.

Compliance for wearing the accelerometer was above 90% for the first day. Regressions, correlations, and paired t-tests indicated that accelerometer measures were stable over a three-day period, although less so for the high-intensity measure. Self-report and accelerometer measures were poorly correlated to each other. High-intensity activity measures were more closely related to well-being than low-intensity measures.

These findings suggest that it is feasible to use accelerometers with the oldest-old. Vigorous activity, measured either by self-report or accelerometer was positively related to well-being, although the low correlation between the measures suggest that they measure different aspects of physical activity.

## Acknowledgements

I wish to express my sincere gratitude to my supervisor, Dr. Verena Menec, for the guidance and support during the course of this thesis. I also wish to thank my other committee members, Dr. Robert Tate and Dr. Judy Chipperfield, for recommendations and feedback.

I am grateful to the Centre on Aging for the Fellowship that they awarded me.

I would like to thank my fellow graduate students and coworkers who have made this learning experience fun.

**Table of contents**

## List of figures

**List of tables**

## BACKGROUND

Physical activity contributes to successful aging by improving and maintaining health in older people. Not only is exercise beneficial to health, but so are less intense activities. Activity questionnaires are often used to assess physical activity, but they may not be valid in older age groups. Accelerometers have been proposed as a substitute for self-report. Unfortunately, they have rarely been used with the elderly. In addition, little research has investigated the relationship between the oldest-old's physical activity and how it relates to health and well-being. The present thesis was designed to examine the feasibility of using accelerometers with the oldest-old, create measures of physical activity with self-report data and accelerometer data, as well as to compare the predictive validity of self-report and accelerometer measures.

### Activity and healthy aging conceptual frameworks

Activity has long been thought to be a key aspect of healthy or successful aging (e.g., Havighurst & Albrecht, 1953). When asked, older adults have also identified activity as a component of healthy aging (Knight & Ricciardelli, 2003; Tate, Lah, & Cuddy, 2003). Several theories have been developed in an attempt to explain this relationship. Havighurst and Albrecht (1953) argued that any loss of roles, activities, or relationships within old age, should be replaced by new roles or activities to ensure happiness, value consensus, and well-being. Lemon, Bengtson, and Peterson (1972) formalized the relationship between activity and healthy aging with activity theory. This theory states that healthy aging depends on a person's ability to maintain social activity. Informal activity is thought to be associated with the most life satisfaction, with formal activity being less strongly associated with life satisfaction, and lastly solitary activities are expected to provide the least life satisfaction.

In contrast, Cumming and Henry (1961) developed disengagement theory, which argues that healthy aging is the result of a gradual decrease in the number and variety of relationships. Also, people are thought to become less concerned with other's approval and more likely to become egocentric as they age.

A third perspective is continuity theory (Neugarten, Havighurst, & Tobin, 1968). It argues that neither disengagement nor high levels of activity determine healthy aging. Instead, healthy aging is a function of the individual's style of adaptation and adjustment that have been developed over the course of his or her life. There may be older people who disengage and are satisfied with their lives, and there may be older people who maintain high activity involvement and are satisfied with their lives. In addition, some people may be dissatisfied with disengagement, while others may be dissatisfied with continued high levels of activity involvement.

Activity theory was later incorporated into the notion of successful aging. Rowe and Kahn (1997) define successful aging as including three main components: low probability of disease and disease-related disability, high cognitive and physical functional capacity, and active engagement in life. Individually, all three are important. The authors argue that successful aging is more fully represented when all three components are combined. However, this perspective may be too stringent. Strawbridge, Wallhagen, and Cohen (2002) found that self-report of successful aging does not strongly relate to Rowe and Kahn's definition. Half the participants considered themselves aging successfully compared with 19% obtained by Rowe and Kahn's criteria.

In a similar approach to continuity theory, Baltes and Baltes (1990) describe a general process of adaptation, referred to as selective optimization with compensation. There are three interacting elements and processes. First, there is the process of selection, whereby an individual's expectations are adjusted to maintain satisfaction and personal control. Second is optimization, whereby people engage in behaviors to enhance and augment their general reserves (biological, mental, and social) and to maximize the quality and quantity of their behaviors. The third element is compensation, which results from restrictions in the range of adaptation. It becomes productive when specific behavioral capacities are lost or reduced below a standard required for adequate functioning. For example, an older adult can reduce the intensity or duration of activities in response to lower capacity.

The relationship between activity and aging can also be explained by considering activity as a personality trait (Rhodes, Courneya, & Jones, 2002; Rhodes, Courneya, & Jones, 2004). Personality is defined as dimensions of individual differences in tendencies to show consistent patterns of thoughts, feelings, and actions, and is hypothesized to represent a biological influence towards culturally conditioned phenomena, behavior, and life events (McCrae et al., 2000; McCrae & Costa, 1995). The activity trait is theorized to be a sub-trait of extraversion (Costa & McCrae, 1995; Eysenck, Barrett, Wilson, &

Jackson, 1992) and conscientiousness (Costa et al., 1995). It represents a predisposition towards being busy, energetic, talkative, and a preference for leading a fast-paced life. Therefore, activity would be an outlet for many individuals high in the activity trait, and unlikely for those low in this trait.

## Definitions

### *Physical activity*

Physical activity has been defined in several ways. A popular definition is provided by Caspersen, Powell, and Christenson (1985), which states that physical activity is any bodily movement produced by skeletal muscles that results in energy expenditure. The measure of physical activity in this case would be energy expenditure.

A definition applicable to questionnaires is provided by Fontane (1996), who defines physical activity on a continuum. At one end of this continuum are activities of daily living (ADLs), such as personal care and eating, which are physical activities associated with self-care. Next are instrumental activities of daily living (IADLs), such as shopping and household chores, which are home management activities. A third category is general activity and exercise, such as gardening, doing errands outside the home, or dancing. An exercise component such as walking, climbing, or lifting is part of the activity, rather than being the purpose. Fourth is fitness exercise, which is regularly practiced, repetitious activity that increases heart rate and uses muscle groups beyond the limits of general activity, such as swimming or tennis. Fifth is exercise training: activity that develops maximum function of muscle and skeletal systems, which are usually tested in competition against standards of time or performance, or other persons.

### *The "oldest-old"*

Given that there is no universal definition of what constitutes very old age and who can be considered the "oldest-old", the term oldest-old is used in the present thesis to refer to individuals who are 80 years and older. This is in line with various definitions that have been provided in the literature. Neugarten (1975) made the distinction between the "young-old" (55-74 years) and the "old-old" (75-plus years). This was based on the assumption that the age of retirement in 2000 would decrease to 55. In the past, the oldest-old were commonly referred to as those 85 years and older. Others have used the term to refer to individuals who are 75 years (e.g., Hamarat et al., 2002; Maurer, Luchsinger, Wellner, Kukuy, & Edwards, 2002), 80 years (e.g., Brockman, 2002; Crystal, Sambamoorthi, Walkup, & Akinicigil, 2003; Hong, Zarit, & Johansson, 2003; Statistics Canada, 2001), or 85 years and older (e.g., Abler & Fretz, 1988; Bootsma-van-der-Wiel-Annetje et al., 2002; Lindenberger & Baltes, 1997; Manton, 1986; Riche, 1985; Rosenwaike & Dolinsky, 1987).

In addition, the definition of the oldest-old is not static (Backman, Small, Forsell, Winblad, & Berger, 1999). Its meaning varies across time and cultures, based on the age distribution of the population. It has also been suggested that the definition should soon be changed to 90 years and older to coincide with the aging population (Denton & Spencer, 2002).

The transition between the young-old and the oldest-old can vary depending upon the criterion used. Using a person-based definition, the maximum lifespan must be estimated for a given individual (Baltes & Smith, 2002). The transition would begin at different ages based on individual lifespans. It could be 60 for some or 90 for others. However, this is not a practical definition. If the transition were the age at which 50% of the birth cohort is no longer alive, then it would be at around 75-80 years of age in developed countries (Baltes et al., 2002). In developing countries, it would be much lower. If the criterion of 50% excludes people who died at younger ages (under 50 or 60 years), the transition would be between 80 and 85 years for developed countries. Therefore, the definition used in the present thesis (80 years or older) satisfies both criteria.

**Benefits of physical activity**

***Physical health***

It has been estimated that 16.6% of total deaths in the United States in 2000 were due to poor diet and physical inactivity (Mokdad, Marks, Stroup, & Gerberding, 2004). The only other health behaviour that caused more deaths was cigarette smoking at 18.1%. Whereas the estimate of total deaths due to cigarette smoking has decreased from 19% in 1990, the estimate for poor diet and physical inactivity has increased from 14% in 1990 (McGinnis & Foege, 1993).

Reviews have consistently found that physical activity provides physical benefits. Blair and Wei (2000) concluded that active and fit persons are at much lower risk for cardiovascular disease and all-cause mortality than sedentary persons. Fozard (1999) concluded that there were weak to moderate associations between higher levels of physical activity and probability of surviving, in addition to fewer chronic medical problems. Schroll (2003) concluded that compared to inactive men and women, the mortality rate was about 60% and the incidence of myocardial infarction 70% in the moderately active.

Many studies have found that a greater level of physical activity is associated with a lower risk of mortality (Sesso, Paffenbarger, Jr., & Lee, 2000; Stessman, Maaravi, Hammerman-Rozenberg, & Cohen, 2000; Wannamethee, Shaper, & Walker, 2000), even among mobility-impaired people (Hirvensalo, Rantanen, & Heikkinen, 2000) and disabled individuals (Ferrucci et al., 1999). In addition, physical inactivity has been found to be a better predictor of all-cause mortality than being overweight or obese (Crespo et al., 2002). In an 11-year follow-up study with 49 to 64 year-old participants, total leisure-time physical activity was inversely related with all-cause, cardiovascular disease, and coronary heart disease mortality (Yu, Yarnell, Sweetnam, & Murray, 2003). However, a trend with cancer deaths was not found. Unlike Yu et al., Rockhill et al. (2001) did find a relationship between physical activity and cancer deaths. In addition, they found that the relationship between physical activity and mortality rate was strongest for respiratory deaths.

In one study, women between the ages of 50 and 101 years with a high level of physical activity had lower systolic blood pressure than less active women (Ellekjaer, Holmen, Ellekjaer, & Vatten, 2000). They also had a lower resting heart rate, and a lower prevalence of coronary heart disease, diabetes, and stroke. More time spent per week in moderate-to-vigorous activity has been associated with lower resting heart rate among both men and women (Mensink, Ziese, & Kok, 1999). In addition, women also had lower systolic blood pressure and body mass index. Physical activity also protects against poor health, irrespective of smoking and increased body mass index (Johansson & Sundquist, 1999).

Falls are a major concern with older adults. One possible outcome of falling is a hip fracture. However, physical activity can help prevent this event. In a review, Buchner (1997) also concluded that exercise does not increase the overall risk of falls. In fact, the evidence showed that the short periods of increased risk of falls during exercise training is more than compensated for by a reduced risk of falls during the rest of the day. Compared with women who were active less than three MET-hours per week (equivalent to walking 3 mph for one hour; Ainsworth, 2002), those with 24 MET-hours per week or higher had 55% lower hip fracture risk (Feskanich, Willett, & Colditz, 2002). Risk declined in a dose-dependent manner with a 6% decrease in risk for every three MET-hours per week increase in activity. If all the participants had exercised at nine MET-hours per week or higher, 23% of the hip fractures could have been prevented. If all exercised at 24 MET-hours per week or higher, 42% of the hip fractures could have been prevented.

Resistance training also has positive effects in older adults. Strength was substantially increased in both men and women aged 60 to 74 years after 12 weeks of resistance training (Kalapotharakos et al., 2004). In addition, a 10-week progressive resistance training program led to significant improvements in muscle strength in institutionalized older adults with a mean age of 81.5 years (Seynnes et al., 2004). In a review, Connelly (2000) found that significant strength improvements in response to resistance training are possible despite advanced age, extremely sedentary habits, multiple chronic diseases, and functional disabilities.

***Mental health***

Although research indicates that physical activity has a positive influence on physical health, the relationship with mental health is less well established. In a review of exercise and mental health, Cooper-Patrick, Ford, Mead, Chang, and Klag (1997) found that many interventional studies of vigorous exercise have failed to show a beneficial effect on mental health. Most studies that did show a negative relationship between exercise and depression included activities like golf and horse back riding. These activities are related to higher social status and larger social networks, which are confounders of physical activity.

However, a meta-analysis by Arent, Landers, and Etnier (2000) found that overall, exercise is associated with improved mood in the elderly. Larger effect sizes were found for resistance training than for cardiovascular exercise. The authors proposed that a decline in mood might accompany the age-related loss of functional abilities caused by deterioration of muscle mass and strength. Daily functioning may be improved through strength training and the psychological improvements may accompany these physical improvements.

Through interviews with a group of older adults who participated in an organized form of regular physical activity, it appears that physical activity contributes to mental health through maintenance of a busy life, mental alertness, positive attitude toward life and avoidance of stress, and to reduced negative function and social isolation (Stathi, Fox, & McKenna, 2002). Physical activity also has a positive effect on meaning in life (Takkinen, Suutama, & Ruoppila, 2001). In a sample of 60 to 74 year-old adults, non-exercisers demonstrated more depressive symptoms than exercisers (d'Epinay & Bickel, 2003). In addition, long-term exercisers demonstrated less depressive symptoms than those who stopped exercising and those who were sedentary. Among 70 to 75 year-old women in a 3-year follow-up study, mental health scores from the SF-36 increased as exercise levels increased (Lee & Russell, 2003). In comparison with the sedentary group, those who stopped exercising showed a significantly greater decrease in mental health, whereas those who adopted or maintained exercise showed less negative changes in mental health.

Another study shows that after 10 weeks of an exercise, education, and stress management program, older adults had lower levels of depression and anxiety, but did not improve their eye-hand coordination (e.g., Finger Tapping test) compared to participants who followed the same program without the exercise and those who were on a waiting list (Emery, Schein, Hauck, & MacIntyre, 1998). In one intervention study, 11 elderly people took a short nap in the early afternoon and exercised at moderate intensity in the late afternoon for four weeks (Tanaka et al., 2002). Not only did sleep quality improve, but mental health as well (as measured by the mental health component of the General Health Questionnaire).

In another intervention study, a group of 60 to 75 year-old sedentary adults completed a 6-month exercise program (McAuley et al., 2000). The intervention group performed aerobic exercise three times per week. The control group performed strength and toning exercises three times per week. Those in the intervention group had increased happiness and satisfaction with life and decreased loneliness over the 6-month intervention period. Participants were also evaluated six months after the intervention was completed. Although the improvements in well-being appeared to be reversed at the 6-month follow-up period, those who exercised more often during the program had less declines in well-being during the follow-up period. Although strength was increased for the intervention group in an 8-week resistance-training program with community-dwelling older adults, the change in mental health functioning did not differ significantly from that of the control group (Damush & Damush, Jr., 1999).

### *Functional status*

A major defining characteristic of good health for older people is functional ability (Keller & Fleury, 2000). Functional status, an individual's capacity to independently carry out necessary daily functions, is often operationalized in terms of activities of daily living and instrumental activities of daily living (Zimmer, Chayovan, Lin, & Natividad, 2004). Several reviews have found that physical activity has positive effects on function in older adults (Blair & Wei, 2000; Fozard, 1999; Schroll, 2003; Spirduso & Cronin, 2001). Long-term physical activity is related to postponed disability and independent living in the oldest-old (Spirduso et al., 2001). In addition, it enhances physical function in individuals with chronic diseases. Older adults were also able to improve their balance, walking, and transfer activities through strengthening and aerobic exercise (Keysor & Jette, 2001). Although Latham, Bennett, Stretton, and Anderson (2004) found that progressive resistance training had a large positive effect on strength, and a small-to-moderate effect on other aspects of impairment and functional limitation, they were unable to find sufficient evidence of improvements in physical disability. Compared to inactive men and women, the incidence of hip fractures was about 75% in the moderately active group (Schroll, 2003).

Seynnes et al. (2004) conducted a study with 22 institutionalized older adults. The participants completed a 10-week progressive resistance-training program. The changes in muscle strength were significantly related to changes in muscle endurance, 6-minute walking distance, chair-rising time, and stair climbing power. However, the researchers did not find an improvement in overall disability score. In women and men, an increase in physical activity is associated with a lower risk of new disability and a higher probability of functional recovery (Ferrucci et al., 1999).

Physical activity may also have an effect on cognitive function. In a 5-year study, older adults with low, moderate, and high levels of physical activity were at lower risk of cognitive impairment – no dementia, any type of dementia, Alzheimer disease, but not vascular type dementia (Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001). However, in a 3-year follow-up study, elderly men who were physically active one hour or less per day did not have significantly more cognitive decline than those who were active more than one hour per day (Schuit, Feskens, Launer, & Kromhout, 2001).

**Types, intensity, and duration of activities**

Older adults are more likely than younger adults to be involved in lower-intensity activities such as walking, gardening, or golf, rather than running, aerobics, or team sports (DiPietro, 2001). They are also more likely to participate in watching television, reading, and shopping (Strain, Grabusic, Searle, & Dunn, 2002). Craig, Russell, Cameron, and Bauman (2004) looked at trends in the prevalence of "sufficiently" active Canadian adults. People were considered sufficiently active if they accumulated an average of 3.0+ MET-hours of leisure-time physical activity daily. In 2000, only 30.7% of Canadian older adults achieved that standard. In a sample of 50 year-old adults followed for 35 years, sports activities consistently decreased from age 50 (Schroll, 2003). Moderate physical activity (4 hours per week) increased from age 50 to 70, but decreased with further aging. Ninety-three percent continued watching television and 91.2% continued reading at an 8-year follow-up. However, only 45% continued outdoor activities. Having better self-reported health and no functional limitations were associated with a greater likelihood of continuing more activities at follow-up.

Several studies have shown that regular and vigorous physical activity has a positive effect on health. Stessman et al. (2000) found that daily exercise was the most protective form of exercise, whereas sports activity twice a week had no protective effect on mortality. Yu et al. (2003) found that light and moderate intensity leisure-time physical activity had inconsistent and non-significant relationships with all-cause, cardiovascular disease, and coronary heart disease mortality. In contrast, a significant dose-response relationship was found for heavy-intensity leisure-time physical activity for all-cause, cardiovascular disease, and coronary heart disease mortality. Compared with women who walked at an easy pace, women reporting walking an average pace had 49% lower risk of hip fracture and women who reported a very brisk pace had a 65% lower risk (Feskanich et al., 2002).

However, an excessive amount of physical activity can have a negative effect on older adults' health. Older adults who reported exercising more than 200 to 300 minutes per week had much lower lumbar spine bone density than sedentary older adults or moderate exercisers (Michel, Lane, Bjorkengren, Bloch, & Fries, 1992).

Although greater health may be attained through high-intensity activities, several studies have shown that the greatest impact on health results from going from inactive to low-active. Men who engaged in small amounts of physical activity (2$^{nd}$ quartile in self-report measure distribution) had a lower risk of dying than those who were inactive (1st quartile; Crespo et al., 2002). Further increases in physical activity did not lead to further decreases in risk of dying. There was also a linear trend toward lower cardiovascular mortality among those who were more physically active, but the largest drop in cardiovascular mortality was between quartile 1 and 2.

Sesso et al. (2000) found an L-shaped association between increasing levels of physical activity and the risk of coronary heart disease, with no additional reduction of coronary heart disease for levels above 8400 kJ per week. 4200 kJ per week can be attained by performing activities such as brisk walking, recreational cycling and swimming, home repair, and yard work for 30 minutes per day (Pate et al., 1995). The greatest decrease in risk of mortality in one sample occurred with an increase in the amount of activity from less than 1 hour per week to 1 to 1.9 hours per week (Rockhill et al., 2001).

Mensink et al. (1999) found that for sedentary older adults, even less physical activity than currently recommended is likely to improve their cardiovascular risk profile (recommended physical activity being five or more times per week and 3.5 hours or more per week). Another reason to encourage older adults to participate in activities other than exercise is that they prefer lower-intensity activities. Chappell (1983) found that doing something relaxing (e.g., playing cards, walking, or talking) with someone their own age brought older people the greatest pleasure.

Although low-activity levels can be beneficial to older adults' health, activity levels must be maintained. In a 5-year follow-up study, the lowest mortality risk was found among men who remained physically active (Bijnen et al., 1999). Men who became inactive had a 72% increased risk of mortality compared with men who remained active, but their risk did not differ significantly from that of men who remained inactive. In a 15-year follow-up study, going from physically active to physically inactive resulted in an increased risk of poor health status (Johansson et al., 1999). Those who decreased their physical activity also increased their mortality risk compared to those who remained physically active. Among women who reported being active at least 4 hours per week at baseline, the risk of hip fracture was doubled among those who decreased to less than 1 hour per week six years later (Feskanich et al., 2002). However, based on studies of both musculoskeletal and cardiorespiratory fitness, it appears that it is never too late for older adults to reap the benefits of increasing their physical activity (Blair et al., 2000).

**Factors related to physical activity**

Several factors have been found to be related to physical activity. In a sample of 2046 adults aged 55 years and older, 81% of women and 73.5% of men reported one or more medical or non-medical reasons why they currently limited or avoided leisure-time physical activity (Satariano, Haight, & Tager, 2000). Women were more likely than men to report that not having an exercise companion was the leading reason. However, the leading reason for men was a lack of interest. With increasing age, men and women were more likely to report medical conditions and a fear of falling as reasons. Women with greater income were less likely to provide reasons for limitation. Reduced walking speed and more depressive symptoms were also associated with providing more reasons.

Among a sample of 65 to 84 year-old participants, Crombie et al. (2004) found that lack of interest in physical activity was the most powerful of all factors, followed by not believing that meeting new people is beneficial, and doubting that exercise lengthens life. Other factors were lack of daily access to a car, painful joints, and dislike of going out alone.

Kaplan, Newsom, McFarland, and Lu (2001) identified several factors related to higher physical levels in the Statistics Canada National Population Health Survey of 1996-1997. The factors were being male, being in the younger segments of old age, not being married, having lower body mass index, less injury, less functional limitations, greater social support, and less psychological distress. Higher physical activity levels have also been found among those with greater perceived control, greater income, and more education (Droomers, Schrijvers, & Mackenbach, 2001). Other factors are not smoking and having fewer health problems (Droomers et al., 2001; Kaplan, Newsom, McFarland, & Lu, 2001).

Initiation of physical activity has been related to being younger, having better health, and believing that being physically active is important to good health (Burton, Shapiro, & German, 1999). Maintenance of physically activity has been associated with more education, having better health, and believing that exercise contributes to good health.

### The oldest-old and physical activity

Little is known about the oldest-old's physical activity and how it relates to health. Although some studies may include oldest-old participants, most do not provide a separate analysis for this age group (e.g., Alexander et al., 2000; Broe et al., 1998; Lord & Menz, 2002; Ostbye, Taylor, & Jung, 2002; Schoenfelder & Rubenstein, 2004; Taylor et al., 2003).

Burton et al. (1999) looked at community-dwelling older adults' physical activity and health outcomes during a 4-year study. Physical activity was defined as a self-report of walking briskly, gardening, or heavy housework at least three times a week. Although a separate analysis of physical activity and health outcomes was not performed for those aged 85 and older, a trend of lower activity as age increased was found. At baseline, 59.6% of those 65 to 74 years old were active, whereas only 21.4% of those 85 years and older were active. They were also less likely to initiate or maintain activity.

Walsh, Pressman, Cauley, and Browner (2001) looked at the percentage of older women who performed common physical activities by age group. Activity decreased as age increased. Some activities decreased faster than others did. Whereas 38% of those 65 to 69 years old were gardening, 23% and 20% of those 80 to 84 and those 85 years old and above, respectively, were still gardening. In comparison, 20% of those 65 to 69 years of age were swimming, and only 5% and 2% of those 80 to 84 and those 85 years old and older, respectively, were swimming.

Ruuskanen and Ruoppila (1995) found that 40% of women aged 80 to 84 and living at home were no more physically active than necessary to perform their daily activities and they did not carry out any form of physical exercise for their health or fitness. Although they did not find a relationship between physical activity and psychological well-being for the same age group, they did find significant relationships between self-rated health and intensive physical exercise. Whereas 13% of those who rated their health as good practiced intensive and regular physical exercise, only 5% of those who rated their health as average or poor did as well.

MacRae et al. (1996) conducted an intervention study, where nursing home residents completed a 12-week walking program. All participants were 80 years of age or older, were unrestrained, and able to start in a sitting position, then stand and walk without assistance. After the 12-week period, the walking group increased their maximum walking time by 77%, whereas the control group's time increased by only 28%. The maximum walking distance increased by 92% in the walking group, whereas the control group's distance increased by 21%. However, falls appeared not to be affected by the intervention.

## Measures of physical activity

### *Questionnaires*

Because of the robust relationships found between subjective health assessments and objective indicators of health status, self-report health measures have come to be viewed as a useful and inexpensive way of characterizing the health status of adults

(Schulz et al., 1994). However, self-report measures of activity in the elderly may not accurately reflect activity levels. This could provide doubt in the accuracy of previous research in activity and health in older adults. Many activity questionnaires in use with older people have been designed for younger populations (Paffenbarger, Jr., Wing, & Hyde, 1978; Sallis et al., 1985; Taylor et al., 1978) and emphasize the more intense activities.

One physical activity questionnaire commonly used with older adults was developed by Paffenbarger et al (1978), which consists of summing the number of flights climbed and number of city blocks walked during the week. Participants are also asked the number of minutes per week they spend in light, moderate, and strenuous sports activities. Each score is multiplied by a weight: stairs x 28; city blocks x 56; light sport x 5; moderate sport x 7.5; and strenuous sport x 10. Scores for each category are summed to provide an overall score. Validity was evaluated by comparing high (> 2000 kilocalories of activity per week) and low activity groups with risk of heart attack. The sample consisted of 16 936 Harvard male alumni aged 35 to 74 years. Follow-up was between 6 and 10 years. The low activity group was at a 64% higher risk for heart attacks than the high activity group.

Another commonly used activity questionnaire is the Minnesota Leisure-Time Physical Activity questionnaire (Taylor et al., 1978). Participants are asked to indicate if they participate in each activity from a list of 64 activities. The interviewer asks which months of the year each activity was done (M), the average number of time per month

(F), and time per occasion (hours or minutes; T). Each activity has an intensity score (I), which vary from mowing the lawn (2.5) to competitive canoeing (12.0). The equation to provide an overall score consists of $\sum(I \times M \times F \times T)$. Validation was obtained by comparing scores with treadmill performances. Activity scores were correlated with the number of minutes needed to reach a variety of heart rate: 130 to 155 beats per minute at increases of 5 beats per minute. Correlations were stronger at higher heart rates.

A third questionnaire commonly used was developed by Sallis (1985). It provides three physical activity scores: moderate, vigorous, and total physical activity. The moderate activity questions consist of 'Do you usually participate in any of the following activities?: climbing some stairs for exercise instead of taking the elevator; walking instead of driving a short distance; parking away from your destination so you have to walk more; walking on your lunch hour or after dinner; getting off at a bus stop which is not the one nearest your destination and walking; and other'. The moderate activity score (from zero to six) consists of summing the number of activities that the individual participates. The vigorous activity questions consist of 'For at least the last three months, which of the following activities have you performed regularly?: jog or run at least 16 kilometers per week; play strenuous racquet sports at least five hours per week; play other strenuous sports at least five hours per week; ride a bicycle at least 80 kilometers per week; and swim at least 3 kilometers per week'. The vigorous activity score (from zero to five) consists of summing the number of activities that the individual participates.

The total physical activity score is an estimation of energy expenditure. Respondents provide the number of hours on weekdays and weekends that they spend participating in moderate, hard, and very hard activities. The number of hours for each category is multiplied by a MET value: 4, 6, and 10 METs for moderate, hard, and very hard activity levels respectively. One MET is 1 kilocalorie per kilogram of body weight per hour and roughly equivalent to quietly sitting (Ainsworth et al., 2000). Respondents also indicate the time spent sleeping, with a weight of 1 MET. Time spent in light activity is determined by what time remains from the weekdays and weekends. Its weight is 1.5 METs. The respondent is provided with examples for each activity intensity: delivering mail on foot, raking the lawn, and volleyball for moderate; heavy carpentry, scrubbing floors, and doubles tennis for hard; and very hard physical labor and jogging or swimming for very hard.

The questionnaires' validity was in part evaluated by correlating the three activity scores to each other. They were poorly correlated with each other (.01 to .15), indicating unique contributions. The scores were also related to personal characteristics. Some support for the validity of the instrument was found in that that the relationships were in the proper direction (e.g., correlations between moderate and vigorous scores were higher in those with more education; women's occupations were related to moderate and vigorous activity; and kilocalorie was related to medium education in men).

Physical activity questionnaires such as these (i.e., age-neutral) have been shown to be inaccurate when used with older people (Cartmel & Moon, 1992; Starling, Matthews, Ades, & Poehlman, 1999; Washburn, Jette, & Janney, 1990). Older persons underreported their physical activities on a questionnaire when compared to a diary of their behaviour. Strenuous activity (e.g., moderate sport and recreation) were least likely to be underreported, whereas less strenuous activity daily activities (e.g., household chores or shopping) were most likely to be underreported. However, questionnaires specifically designed for older adults have been developed recently. Evidence for their validity is limited, but what is available indicates that they are as valid for older adults as age-neutral questionnaires are for younger populations (Harada, Chiu, King, & Stewart, 2001; Washburn, 2000).

The Community Healthy Activities Model Program for Seniors (CHAMPS) questionnaire includes lighter forms of physical activity, such as walking leisurely and stretching, as well as more vigorous activities (Stewart et al., 2001). It estimates weekly frequency of participation and energy expenditure in physical activities that could lead to health benefits. Respondents are asked to report the total time spent per week for each activity. The questionnaire also included activities other than physical activity (e.g., social activities, hobbies) to avoid social desirability (i.e., physically inactive individuals providing affirmative responses to activities they should not). All activities were provided with a MET value from a published compendium of physical activities, which was determined from a younger population. Some values were adjusted because they would exceed older adults' aerobic capacity and muscle strength. One of the authors and another expert in MET values determined these adjustments.

To evaluate the questionnaire, a sample of 249 older adults including inactive, somewhat sedentary, and active individuals completed the questionnaire, and were reevaluated two weeks and six months later. Two-week test-retest analyses provided correlations of 0.76 for moderate and vigorous activities and 0.62 for all activities. The 6-month test-retest analyses provided correlations of 0.67 for moderate and greater energy expenditure and 0.66 for all activities, indicating considerable stability over time. Activity scores for the three groups (inactive, somewhat sedentary, and active) were significantly different between groups. Validity was also determined by correlating scores with various health measures and non-health measures. Evidence for the validity of the questionnaire would be demonstrated if the scores were more strongly related to health than non-health measures. The scores were indeed more strongly correlated with lower body functioning, a 6-min walk test, self-reported physical functioning, and self-reported energy/fatigue ($r=0.17$ to $0.30$) than with pain and psychological well-being ($r=0.05$ to $0.11$).

The Yale Physical Activity Survey (YPAS; DiPietro, Caspersen, Ostfeld, & Nadel, 1993) estimates time spent in 25 activities during a typical week of the last month. The activities fall under the categories of work, yard work, care taking, exercise, and recreational activities. Time spent in each activity is multiplied by an intensity code (kcal/min) and then summed across all activities to create an overall score. Respondents are also asked to estimate the frequency and duration of vigorous activity, leisurely walking, moving, standing, and sitting. Weights are assigned to each category (vigorous:

5; leisurely walking: 4; moving: 3; standing: 2; sitting: 1). Frequency is multiplied by duration and then multiplied by the weighting factor to provide a score for each category.

A sample of 59 participants completed the questionnaire and scores were correlated with energy expenditure (Young, Jee, & Appel, 2001). Energy expenditure was non-significantly correlated with estimated energy expenditure (r=0.20) and total time (r=0.11). It was significantly correlated with the overall summary index (r=0.33), moving index (r=0.36), and standing index (r=0.28), but not with the vigorous activity, leisurely walking, and sitting indexes (r=0.06-0.23), suggesting that the summary, moving, and standing indices would be more appropriate to measure physical activity than the other indices.

***Accelerometers***

An alternative to self-report measures of physical activity is the use of accelerometers. Accelerometers are light, watch size instruments that provide continuous recording of movement, which can then be downloaded for computer analysis (Computer Science, 1995). Accelerometers are reliable and valid measures of movement (Tudor-Locke & Myers, 2001). There are several accelerometers available for use, such as the ActiGraph, Caltrac, and Dynalog.

*Validity.* ActiGraph readings have been correlated with physiological measures and self-report measures of physical activity. Sallis et al. (1996), with the Caltrac accelerometer, found correlations ranging between .30 and .38 with children's self-reported physical activity (i.e., minutes of moderate and vigorous physical activity correlated with moderate and vigorous physical activity MET scores). In another study with children, fifteen children each wore an ActiGraph and went through a field trial (Brage, Wedderkopp, Andersen, & Froberg, 2003a). They walked and ran at four preset speeds (two for walking and two for running). Mean ActiGraph scores were positively related to speed and heart rate ($r^2 = 0.55$ and 0.60 respectively).

Under free-living conditions, using an accelerometer they developed themselves, Meijer, Westerterp, Koper, and ten Hoor (1989) found a correlation of .99 with energy intake, which was used as an estimate of energy expenditure. Davies, Jordan, and Lipkin (1992) used the Dynalog accelerometer and found correlations of .72 and .60 with an activity questionnaire (measuring everyday physical activity) when the accelerometer was worn on the ankle and on the wrist, respectively. They also found correlations of .41 and .42 with VO2max when it was worn on the ankle and on the wrist, respectively.

A group of 12 male participants wore an ActiGraph on each hip, as well as a pedometer (Brage, Wedderkopp, Franks, Andersen, & Froberg, 2003b). They performed walking and running sessions on a treadmill and a field trial with the same protocol: increasing speed after 5-minute intervals starting from 3 to 6 km/h (walking) and 8 to 20 km/h (running). $VO_2$max was also measured. Mean ActiGraph scores were correlated with speed and $VO_2$max. ActiGraph readings increased linearly with increasing speed until 9 km/h ($r^2$=0.92) and remained at the same ActiGraph level past this speed.

Estimation error increased from 11% at 10 km/h to 48% at 16 km/h. This indicates ActiGraphs may not be appropriate for high-intensity activities.

Patterson et al. (1993) found correlations of .73 and .71 between ActiGraph means with maximum oxygen intake ($VO_2max$) and heart rate respectively, when participants were performing various physical activities (i.e., walking/running on a treadmill, stepping up and down on an 8-inch step, and performing knee bends). The authors also found correlations of .46 and .35 with $VO_2max$ (maximum oxygen uptake) and heart rate, respectively, when participants performed sedentary activities (i.e., reading, typing, and video games). In another study, individuals in wheelchairs wore ActiGraphs on both wrists and went three times over an indoor course at three speeds (Washburn & Copay, 1999). ActiGraphs were correlated to energy expenditure: $r = 0.66$ for the left wrist and $r = 0.52$ for the right wrist.

Accelerometers have also been able to differentiate activities of various intensities. Patterson et al. (1993) found that ActiGraph readings could distinguish between walking/running speeds that elicit 30, 60, 75, and 90% of each participant's VO2max. They could also distinguish between stepping up and down on a step at rates of 20 and 36 steps per minute. In addition, the ActiGraph readings could distinguish between performing knee bends at 28 and 48 bends per minute. Sugimoto, Hara, Findley, and Yonemoto (1997) found that accelerometer readings from the Mini Motion Logger could distinguish physical activities in six categories of intensity, from sleeping or a lying position to jogging and lifting heavy objects.

A few studies have included older adults when validating accelerometers. Gardner and Poehlman (1998) used the Caltrac accelerometer to assess daily physical movements of 22 patients suffering from peripheral arterial occlusive disease. The accelerometers were worn slightly above the hip. Patients were instructed to wear them during the waking hours and to remove them before going to bed for a two-day period. The accelerometer readings were converted into caloric expenditure.

Total daily energy expenditure was determined over a 10-day period using the doubly-labeled water technique. This technique calculates the elimination rates of oxygen and hydrogen turnover in the human body's water and assumes that they are related to the rate of carbon dioxide production, which is the measure of energy expenditure (Speakman, 1998). Resting energy expenditure was calculated by using oxygen consumption and carbon dioxide production during 45 minutes of supine rest with a calorimeter. Energy expenditure of physical activity was calculated by subtracting resting energy expenditure from daily energy expenditure. Participants also completed three physical activity questionnaires. The results indicated that energy expenditure of physical activity was highly correlated with the accelerometer readings ($r = .83$) but not with the physical activity questionnaires ($r = 0.06$ for Stanford 7-day Recall; $r = 0.07$ for Minnesota Leisure Time Physical Activity; $r = 0.15$ for a 1-item scale).

Kochersberger, McConnell, Kuchibhatla, and Pieper (1996) evaluated the validity of the Tritrac accelerometer with nursing home residents. Nursing staff members from a nursing home were asked to categorize patients as being “active”, “moderately active”, or “sedentary” based on the amount of time spent sitting in a chair or wheelchair, endurance during ambulation, and speed and independence in mobility (walking and wheelchair). Ten elderly residents in each category were recruited from a nursing home, and wore an accelerometer for six hours (9 AM to 3 PM). The nursing home patients categorized as sedentary, moderately active, and active had significantly different mean activity scores. The eight participants who walked on the treadmill also wore a Motion Logger accelerometer. The minute-by-minute correlation of activity with the accelerometer was 0.77. Another study included 50 older adults with chronic disease (Focht, Sanders, Brubaker, & Rejeski, 2003). The first trial consisted of a 30-minute walk and energy expenditure was estimated for each participant. The second trial consisted of 30 minutes of rehabilitative exercise and the outcome measure was oxygen uptake. Mean ActiGraph scores were correlated with estimated METs ($r = 0.60$) and oxygen uptake ($r = 0.72$).

Some activities may not be accurately measured with accelerometers, however. For example, resistance training may be more accurately assessed through physical activity questionnaires (Lowther, Mutrie, Loughlan, & McFarlane, 1999) and sedentary activities (e.g., playing video games) requiring higher than normal wrist movement can produce accelerometer readings comparable to those of physical activities, such as walking (Patterson et al., 1993). In addition, accelerometers may more accurately assess low activity levels (Leidy, Abbott, & Fedenko, 1997; Starling et al., 1999). Although accelerometers have recently become more common in activity research, they have mostly been limited to validating self-report measures (Wilcox, Tudor-Locke, & Ainsworth, 2002).

*Reliability.* In a laboratory setting, 12 male subjects performed treadmill walking/running sessions while wearing an ActiGraph on both hips and a pedometer. They also participated in a field trial with the same protocol, which involved increasing speed after five-minute intervals from 3 to 6 km/h (walking session) and 8 to 20 km/h (running session; Brage et al., 2003b). Results indicated that there were no significant differences in the ActiGraph readings-speed relationship between the treadmill and field trial.

Kochersberger, McConnell, Kuchibhatla, and Pieper (1996) conducted a study with eight elderly participants to evaluate the test-retest reliability of the Tritrac accelerometer. The participants walked on a treadmill at one and two miles per hour for five minutes each. They repeated those two activities five minutes later. The test-retest reliability revealed a correlation of 0.97.

Although reliability studies with humans have demonstrated accelerometers are reliable, technical trials can produce more accurate test-retest results by reducing error found in other types of studies. One technical trial using a motorized turntable tested 23 ActiGraphs at two fixed baseline speeds (fast: 120 revolutions per minute; medium: 72 revolutions per minute; Metcalf, Curnow, Evans, Voss, & Wilkin, 2002). The turntable was driven by a DC electric motor via a power amplifier. A signal generator that allowed amplitude and frequency of the drive signal to be accurately and reproducibly set provided the amplifier input. The amplitude and frequency corresponded to constant acceleration and rate of change of acceleration respectively, which were sensed by the devices when attached to the turntable. Therefore, changes could be simulated for acceleration at different rates of change and based on different baseline acceleration. Each test lasted 10 minutes. Results indicated no significant differences in intra- and inter-variation at both speeds.

*Length of assessment.* Research indicates that four days or more is recommended to accurately assess habitual physical activity in children. Janz (1994) used ActiGraphs in her study, which included 31 children ranging from 7 to 15 years old. Children wore an ActiGraph in a small pouch over their right hip for three days. The measures were mean activity counts and number of minutes spent at $\geq$ 256 counts/min/day. The results indicated that there were no significant differences between-day group means. However, the results provided moderate correlations, ranging from .23 to .53 between Days 1 and 2, 1 and 3, and 2 and 3. Janz concluded that more than three days would be needed to obtain stable ActiGraph readings.

Janz, Witt, and Mahoney (1995) conducted a similar study. They found moderate intraclass correlation coefficients (0.42 to 0.47) at day 1 for mean counts and frequency at sedentary, moderate, and vigorous activity. The correlations rose above 0.80 on day 6. The authors concluded that four days of monitoring would be needed to obtain a correlation of 0.70.

Trost, Pate, Freedson, Sallis, and Taylor (2000) conducted a study with 381 students from grades 1 to 12. They wore an ActiGraph over their right hip for seven days. Moderate, vigorous, and very vigorous physical activity were determined to be 3 to 5.9, 6 to 8.9, and above 9 MET per hour, respectively. The physical activity levels in accelerometer readings were determined using the energy expenditure prediction equation developed by Freedson, Melanson, and Sirard (1998). Overall, the intraclass correlations of moderate-vigorous physical activity scores derived from a single day of monitoring were low, ranging from 0.31 for grades 10 to 12 to 0.46 for grades 1 to 3. In contrast, the intraclass correlations of daily moderate-vigorous physical activity scores derived from seven days of monitoring were acceptable ($\geq 0.70$).

Matthews, Ainsworth, Thompson, and Bassett, Jr. (2002) conducted a study where 92 adults between the ages of 18 to 79 years wore an ActiGraph for three weeks. They estimated that at least three or four days would be required to achieve a reliability of 80% with moderate to vigorous activity. A reliability of 90% would require at least seven days of monitoring.

Despite the recommendations for younger age groups, the optimal length of time to wear an accelerometer to assess habitual physical activity in the elderly has not been determined. Based on self-report measures, there appears to be day-to-day variability in older adults' activity levels (Dallosso et al., 1988). Older adults reported walking was greatest on Fridays (77%) and least on Sundays (35%). Matthews, Ainsworth, Thompson, and Bassett, Jr. (2002) did not find a day-of-the-week effect (i.e., more active on one day of the week) for 60 to 79 year-old adults who wore an ActiGraph for three weeks.

In addition, Korchersberger, McConnell, Kuchibhatla, and Pieper (1996) conducted a study with 36 community-dwelling older adults who were participating in an in-home exercise program and wore the Tritrac accelerometer. They were asked to wear an accelerometer for one week. Fourteen of the participants were asked to wear it again for a second week. The participants showed great stability in accelerometer readings. The intraclass correlation coefficients for mean daily readings were above .80, and .78 for sedentary activity (< 20 activity units/min). In addition, there were no significant between-week differences for participants who wore the accelerometer for a second week.

## OVERVIEW OF THE PRESENT STUDY

In the present thesis, a sample of 100 oldest-old Winnipeg residents were asked to respond to a questionnaire that included questions related to activity and well-being. Other variables included age, gender, a single-item energy measure, a single-item self-rated health measure, living arrangements, physical function and a perceived control scale, which were used either to validate measures or as control variables in some of the analyses.

With respect to activity measures, the questionnaire included a single-item activity scale, as well as a leisure activity index. The index was composed of 28 common activities that very elderly individuals typically engage in and respondents indicated for each activity the frequency and duration of activity participation, as well as how physically active (physical involvement) they perceived themselves to be while engaging in the activity. The first step of the present thesis was to develop self-report physical activity measures using the activity index. Two measures of physical activity were developed that were designed to reflect different levels of activity participation: moderate- and high-intensity. A systematic approach was taken to derive each of these measures, including validation against energy, physical function, and self-rated health measures, consistent with previous validation studies (Dubbert, Vander Weg, Kirchner, & Shaw, 2004; Harada et al., 2001; Stewart et al., 2001).

Participants were also asked to wear an ActiGraph for three days or less. Research indicates that children must wear an accelerometer for at least four days, but it would be preferable for the oldest-old to wear it for a shorter period. Their skin is sensitive (Shephard, 1997) and the wristband may be uncomfortable if worn for a long period. It is also unknown how long the oldest-old are willing to wear an accelerometer. The oldest-old may not be willing to wear an accelerometer for a long period because they might see it as a burden and lose interest. However, accelerometer research including older adults has indicated that one day may be all that is needed (Kochersberger, McConnell, Kuchibhatla, & Pieper, 1996; Matthews, Ainsworth, Thompson, & Bassett, Jr., 2002). Therefore, it would be favorable to ask them to wear it for a short period (e.g., 3 days) rather than a longer period (e.g., one week). Some issues addressed in the present study included whether the oldest-old were willing to wear an ActiGraph for three days and determining how many days an ActiGraph must be worn to acquire stable readings between days.

Given that there are different ways in which ActiGraph data can be used and there is no single best approach, three measures were derived in the present thesis: an average (mean) score and the proportion of time spent in moderate- and in vigorous-intensity activity, respectively. The mean consisted of averaging the data. The moderate- and vigorous-intensity measures were determined with the help of MET values and mean ActiGraph scores for a variety of activities obtained from another study (Swartz et al., 2000). The resulting cut-off points were used to calculate the proportion of time spent in moderate- and in vigorous-intensity activity, respectively.

The relationship between self-report activity measures and ActiGraph measures was also examined in the present thesis, in order to determine how well they correlated with each other. Higher correlations between measures of similar intensities and lower correlations between measures of different intensities would provide some validation for these measures.

Lastly, the relationship between the different activity measures and well-being (depression and happiness) was examined to address the issue of predictive validity. Measures of well-being were used here, as intervention studies have shown that well-being is improved after participating in physical activity (Emery et al., 1998; McAuley et al., 2000; Tanaka et al., 2002). Strong relationships between activity measures and well-being would provide evidence for the validity of the activity measures.

Several approaches were used to examine predictive validity. First, each activity measure was examined separately to determine its unique relationship with the well-being measures. Second, self-report and Actigraph that were similar (e.g., the moderate self-report and moderate ActiGraph scores) were examined together to determine which is more strongly related to well-being when controlling for both measures. Third, both moderate- and high-intensity activity measures were examined together (e.g., moderate and hard self-report) to determine the unique relationship with well-being when controlling for both intensities

**OBJECTIVES**

The objectives of the present study were to:

1. determine the oldest-old's compliance of wearing an ActiGraph.
2. examine the stability of ActiGraph readings over a three-day period.
3. examine the relationship between self-reported physical activity and ActiGraph scores.
4. compare the predictive validity of self-reported physical activity and ActiGraph scores.

## METHODS

### Data source and sample

Secondary data was used for the present Master's thesis. It was provided by Dr. Verena Menec's pilot study of activity and successful aging among the oldest-old. The data was collected from October 2003 to February 2004. The study drew on participants of the Aging in Manitoba study (AIM).

An initial random sample of 100 individuals was chosen from the AIM database. Those who were not living in a personal care home at the time of the interview, those without cognitive impairments (i.e., who scored 7 or above on the MSQ test at the last AIM interview), and those living in Winnipeg were eligible to participate. One individual was found to be cognitively impaired during the pilot study interview and was replaced by another participant, resulting in a sample of 101.

The sample was stratified by age (80 – 84 and 85+ years old), gender, and type of dwelling (i.e., a house versus an apartment). There were eight categories: male-younger-apartment, male-older-apartment, male-younger-house, male-older-house, female-younger-apartment, female-older-apartment, female-younger-house, and female-older-house. If participants from the initial list of random participants could not, or did not want to participate, an individual from an alternate list (but same category) was selected. If replacements were needed and there was nobody left in the same category from the alternate list to serve as a replacement, an individual from the corresponding category but opposite gender was used.

Two experienced interviewers administered a questionnaire. The average length of time to complete the interview was approximately one hour and 10 minutes. Forty-six men and 55 women participated (see Table 1 for sample characteristics). Twenty-four participants lived in seniors apartments and the other 77 participants lived in other types of residences. The age ranged from 80 to 101. The mean age was 85.60 with a standard deviation of 5.03. However, one participant did not answer the CES-D questions, three participants did not answer the perceived control questions, three participants refused to wear an ActiGraph, an ActiGraph malfunctioned for one participant (therefore has no ActiGraph score), and two participants did not wear the ActiGraph long enough to provide scores, which resulted in a final sample of 91.

The Health Research Ethics Board at the University of Manitoba provided ethical approval for this thesis.

## Measures

### *Single-item activity measure*

The questionnaire included a one-item self-report measure of physical activity: "In general, compared to others your age, how active are you?" (1 = much less; 7 = much more). See Figure 1 for the distribution of this activity measure. Although it roughly follows a normal distribution, it was dichotomized (0 = 1 to 4; 1 = 5 to 7) for regression analyses to be consistent with the other activity measures, which were skewed.

Table 1. Sample characteristics

| Variables | Codes or Ranges | Mean (SD) or % |
|---|---|---|
| Gender | 0 = male | 46.4% |
| | 1 = female | 53.6% |
| Age | 80-101 years | 85.60 (5.03) |
| Self-reported physical activity | | |
| 1-item self-report measure | 0 = low | 42.3% |
| | 1 = high | 57.7% |
| Moderate | 0 = low | 49.4% |
| | 1 = high | 50.5% |
| Hard | 0 = low | 49.5% |
| | 1 = high | 50.5% |
| ActiGraph measure | | |
| Mean | 0 = low | 49.5% |
| | 1 = high | 50.5% |
| Moderate | 0 = low | 49.5% |
| | 1 = high | 50.5% |
| Vigorous | 0 = low | 48.4% |
| | 1 = high | 51.6% |
| Activity tertiles | | |
| 1-item scale | 0 = reference | 42.3% |
| | 1 = 2nd tertile | 38.1% |
| | 1 = top tertile | 19.6% |
| Moderate self-report | 0 = reference | 35.1% |
| | 1 = 2nd tertile | 32.0% |
| | 1 = top tertile | 33.0% |
| Hard self-report | 0 = reference | 28.9% |
| | 1 = 2nd tertile | 37.1% |
| | 1 = top tertile | 34.0% |
| ActiGraph mean | 0 = reference | 33.7% |
| | 1 = 2nd tertile | 32.6% |
| | 1 = top tertile | 33.7% |
| Moderate ActiGraph | 0 = reference | 31.6% |
| | 1 = 2nd tertile | 34.7% |
| | 1 = top tertile | 33.7% |
| Vigorous ActiGraph | 0 = reference | 32.6% |
| | 1 = 2nd tertile | 33.7% |
| | 1 = top tertile | 33.7% |
| Living arrangements | 0 = not living with another adult | 52.6% |
| | 1 = living with another adult | 47.4% |
| Self-rated health | 1-5 | 3.49 |
| Energy | 1-7 | 4.40 (1.34) |
| Physical function | 0 = low (able of less than 11 activities) | 53.6% |
| | 1 = high (able of all 11 activities) | 46.4% |
| Perceived control | 1-10 | 7.43 (1.42) |
| CESD squared | 1-9 | 5.90 (2.08) |
| SHARP squared | 0-1 | 0.63 (0.25) |

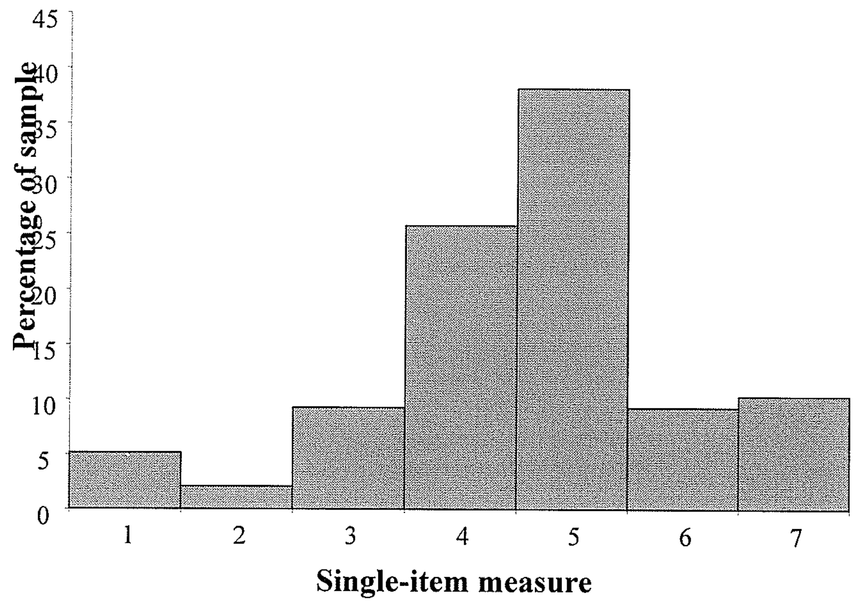



Figure 1. Distribution of single-item physical activity measure.

***Leisure activity index***

The questionnaire also included a 28-item leisure activity index that includes activities that have been found relevant for the oldest-old (Horgas, Wilms, & Baltes, 1998), namely: social activities (e.g., visiting friends), solitary activities (e.g., reading), personal maintenance and instrumental activities of daily living (e.g., personal grooming), and physical activities (e.g., walking). Participants indicated the usual duration of each activity at any one time in hours or minutes. They also indicated the frequency with which they participate in each activity: 0 = never; 7 = several times a day). For each activity participants also indicated how physically active (i.e., physically involved) they were when performing the activity: 1 = not at all; 5 = extremely. See the 'Results' section for a description of how specific activities were classified as moderate or hard. The moderate and hard self-report measures were skewed and had to be dichotomized for regression analyses.

### *ActiGraph*

ActiGraphs were worn on the non-dominant wrist. The wrist was chosen because it was assumed this area would provide a more representative measure of physical activity than other locations (i.e., participants would mostly perform sedentary activities with wrist movements and little waist movement). Half of the participants were asked to wear the ActiGraph for one day and the other half for three days. Whether participants wore the ActiGraph for one or three days was determined by the location of the participant's residence. Participants were divided by two geographical areas. One interviewer was allocated one area, with participants being asked to wear the ActiGraph for one day, and the second interviewer was allocated the other area, with participants being asked to wear the ActiGraph for three days.

The ActiGraphs assessed accelerations ranging from 0.05 to 2.0 G and frequencies from 0.25 to 2.5 Hz (Computer Science, 1995). These parameters detect normal body motion and filter out high frequency movements, such as vibrations. The ActiGraph reports physical activity in units called activity counts. Activity counts are the summation of the accelerations measured during one cycle. One cycle for this study consisted of one minute. A higher number of activity counts during one cycle represents greater physical activity by the participant. See the 'Results' section for the construction of mean, moderate, and vigorous ActiGraph measures. The moderate and vigorous measures were skewed, but the mean scores were not. For consistency, all three measures were dichotomized for the regression analyses.

### *Demographic variables*

Demographic variables included in the present thesis are age (0=younger, 80-84; 1=older, 85+ years old), gender (0=male, 1=female), and living arrangement (i.e., whether or not they were living with another adult: 0=not living with another adult, 1=living with another adult). Age was included as a categorical variable in the first two objectives and included as a continuous variable in the fourth objective.

### *Self-rated health*

Self-rated health was measured with a question commonly used in gerontological research, "For your age, would you say in general your health is [1=bad, 2=poor, 3=fair, 4=good, and 5=excellent]. The measure was included as a continuous variable in all analyses.

### *Energy*

Energy was measured with the question, "In general, compared to others your age, how much energy do you have?" Possible responses varied from '1 = much less' to '7 = much more'. The measure was included as a continuous variable in all analyses.

### *Physical functioning*

Activities of daily living (ADL; Branch & Jette, 1982; Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963), which are defined here as a measure of functional capacity, rather than a measure of activity, was measured with 11 items, and participants were asked whether they were capable of accomplishing specific tasks: going up and down the stairs; getting about the house; going out of doors in good weather; going out of doors in any weather; getting in and out of bed; washing or bathing or grooming; cutting toenails; eating; taking medication or treatment; using the toilet; and managing financial matters. Respondents answered yes (= 0) or no (= 1) to each item. The items answered negatively were summed to provide an overall score. The internal reliability of the scale was adequate with a Cronbach alpha of 0.72. Using the overall scores, participants were separated into those with and without functional problems: those with one or more negative responses were categorized as having functional problems and those with no negative responses were categorized as having no functional problems.

***Perceived control***

Perceived control was measured with 11 items (Chipperfield, Perry, Volk, & Hladkyj, 2003; Chipperfield, Campbell, & Perry, 2004). Participants were asked how much influence they felt they had over several personal aspects (1 = almost no influence; 10 = total influence): your physical health; where you live or will be living; who you spend your time with; the things you can do for fun and enjoyment; developing new friendships; your physical fitness; your physical comfort or discomfort; your emotional or mental well-being; the basic things you must do just to looks after yourself (e.g., bathing, eating, etc.); the usual tasks that need to be done (e.g., housework, yard work, shopping, laundry); and your life in general (alpha = 0.91).

### *Well-being*

Two well-being measures were used in this thesis: the Centre of Epidemiological Studies Depression Scale (CES-D; Radloff, 1977) and the Memorial University of NewFoundland Scale of Happiness (SHARP; Stones & Kozma, 1986). The CES-D is composed of 10 items, which asks respondents how they felt during the past week: I was bothered by things that don't usually bother me; I had trouble keeping my mind on what I was doing; I felt depressed; I felt that everything I did was an effort; I felt hopeful about the future; I felt fearful; my sleep was restless; I was happy; I felt lonely; and I could not get going. Each item is scored on a scale of 0 to 3 (0 = rarely or some of the time; 3 = most or all of the time). Because the questions were not all affirmative or negative, they were recoded so that a higher score represents greater well-being. An overall score is provided by summing the scores of each item (alpha = 0.76).

The SHARP is composed of 12 items, which asks respondents how they felt during the past month: in high spirits; particularly content with your life; depressed or very unhappy; flustered because you didn't know what to do; bitter about the way your life has turned out; generally satisfied with the way your life has turned out; things are getting worse as I get older; little things bother me more this year; life is hard for me most of the time; I am satisfied with my life today; I am just as happy as when I was younger; and as I look back on my life, I am fairly well satisfied. Respondents answer yes (= 1) or no (= 0) to each item. Because the questions were not all affirmative or negative, they were recoded so that a higher score represents greater well-being. An overall score is provided by summing affirmative responses (alpha = 0.69). Both CES-D and SHARP scores were squared because their distributions were skewed (see Appendix A for normality plots of both measures before and after transformation).

These reliable and valid measures have been used extensively with older adults (e.g., Bierman, Bubolz, Fisher, & Wasson, 1999; Gilbart & Hirdes, 2000; Kimberlin, Pendergast, Berardo, & McKenzie, 1998; Robertson, Rockwood, & Stolee, 1982).

**Analyses**

To address objective 1 (determining the oldest-old's compliance of wearing an ActiGraph), Kaplan-Meier curves were created for the overall group, gender, and age groups for those who were asked to wear the ActiGraph for three days. A participant was categorized as compliant if he or she was wearing the ActiGraph approximately three days, as per instructions. Based on the data, participants who were wearing the ActiGraph for 63 hours or longer were considered compliant. The time an ActiGraph was worn by a compliant participant was considered a censored observation, that is, an observation with incomplete information. If the participants were allowed to wear the ActiGraph for a longer period, it would have been possible to observe the participants removing the ActiGraph and their information would not have been censored. Whether compliance varied across gender, age, and health outcomes was examined with logistic regressions. The outcome measure was the whether or not participants wore the AcitGraph for 63 hours (yes, no). Gender, age, and measures of health and well-being were included as predictors to determine whether these factors may have an effect on compliance. Health measures included self-rated health, physical functioning, and energy. Well-being measures included CES-D (depression) and SHARP (happiness). These measures were included in univariate analyses (i.e., one predictor at a time).

To address objective 2 (examining the stability of ActiGraph readings over a three-day period), I used intercepts and slopes from regression models, Pearson correlations, two-tailed paired t-tests, and analysis of variance (ANOVA). Day means were included in simple regression models to determine if intercepts and slopes significantly deviate from 0 and 1 respectively. If means are identical from one day to the next, a regression line would have an intercept of 0 and a slope of 1. A significant deviation from either would indicate instability between days. Pearson correlations were used to calculate the association between 1-, 2-, and 3-day means.

Two-tailed paired t-tests were used to compare the 1-, 2-, and 3-day means. Group means and standard deviations were used to compare the means of each day of the week to determine if there was a day-of-the-week effect (see pp. 58 – 66 for a description of how these variables were created). Proportion of time spent in moderate and vigorous physical activity levels were also examined using the same methods as mean ActiGraph counts (i.e., regression, Pearson correlation, two-tailed paired t test, and ANOVA). Whether stability varies across gender and age was also examined. One-, 2-, and 3-day, and overall ActiGraph scores for those who wore the ActiGraph for three days were also correlated with depression and happiness scales. Similar correlations between days would indicate stability between days.

To address objective 3 (examining the association between self-reported physical activity and ActiGraph scores), I used Spearman correlations and kappa. Spearman correlations were used to correlate the six physical activity measures to each other. The three self-report measures were the 1-item measure, and the moderate- and high-intensity self-reported physical activity measures. The three ActiGraph measures were the mean, moderate, and vigorous ActiGraph scores. Activity measures of the same intensity should be more strongly correlated to each other than with activity measures of different intensities (e.g., the hard self-report more closely related to the vigorous ActiGraph score than the mean ActiGraph score). Spearman correlations were used because most measures had skewed distributions.

The high-intensity self-reported physical activity and vigorous ActiGraph measures were used to determine the kappa statistic. Each measure was divided into tertiles to produce three intensity levels: low, moderate, and high. The high-intensity measures were included because physical activity measures are often categorized as high-intensity activity.

To address objective 4 (comparing the predictive validity of self-reported physical activity and ActiGraph scores), I used multiple regressions and ANOVAs. Multiple regressions were used to determined predictive validity. Regression models included activity measures that were dichotomized and grouped into tertiles. This was done to provide sensitivity analyses. Activity measures were included in a regression model as binary variables (low and high activity levels). The analysis was then repeated with tertile levels (low, moderate, and high).

Three series of regression models were produced. First, all activity measures were included in separate regression models. Second, to produce between-measure comparisons, activity measures of similar intensity were included in the same regression models (i.e., the single-item measure included with the mean ActiGraph score; the moderate-intensity self-reported physical activity measure included with the moderate-intensity ActiGraph measure; and the hard self-reported physical activity measure included with the vigorous-intensity ActiGraph measure). Third, to produce within-measure comparisons, moderate- and hard-intensity self-report measures were included in the same model, whereas the moderate- and vigorous-intensity ActiGraph scores were included in another model. Activity measures were entered as binary and tertiles in separate regression models.

In addition, the following control variables were included into the models: age, gender, functional health, self-rated health, living arrangement, and perceived control. These variables were included as covariates because they have been associated with physical activity and health in previous research (e.g., Droomers et al., 2001; Kaplan et al., 2001; Menec & Chipperfield, 1997; Due to the small sample size, control variables were entered one at a time and only those with a significant effect were kept in the regression model.

ANOVAs were also used to determine the predictive validity of high-intensity physical activity measures. The high-intensity self-reported physical activity and vigorous ActiGraph measures were included in the ANOVAs. Each measure included three levels: low, moderate, and high. The high-intensity measures were included because physical activity measures are often categorized as high-intensity activity. Three types of ANOVA were computed: both activity measures entered one at time in separate models; both activity measures in the same model; and both activity measures and their interaction in the same model. Data were analyzed with SAS 9.1.

## RESULTS

The following Result section is divided into five major sections. First, the development of the activity measures is described (including the development of both the self-report and ActiGraph measures of physical activity). Results pertaining to Objectives 1 to 4 are discussed in the subsequent four sections, respectively.

### Preliminary analyses - Development of physical activity measures

#### *Self-report activity measures*

I used three self-report physical activity measures in this thesis. The first was a single item measure derived directly from the survey. The remaining two – participation in moderate and hard intensity activity had to be developed. In this section, I will discuss how I created the latter two measures from the Leisure Activity Index.

The first step was to classify activities from the leisure activity index into moderate- and high-intensity activities by using a Kaplan-Meier curve. For each activity, the mean of the responses to the physical involvement question (1=not at all, 5=extremely) was taken. A Kaplan-Meier curve was then produced to sort the activities by their mean physical involvement and provide a visualization of the proportion of activities above each mean physical involvement score (see Figure 2).

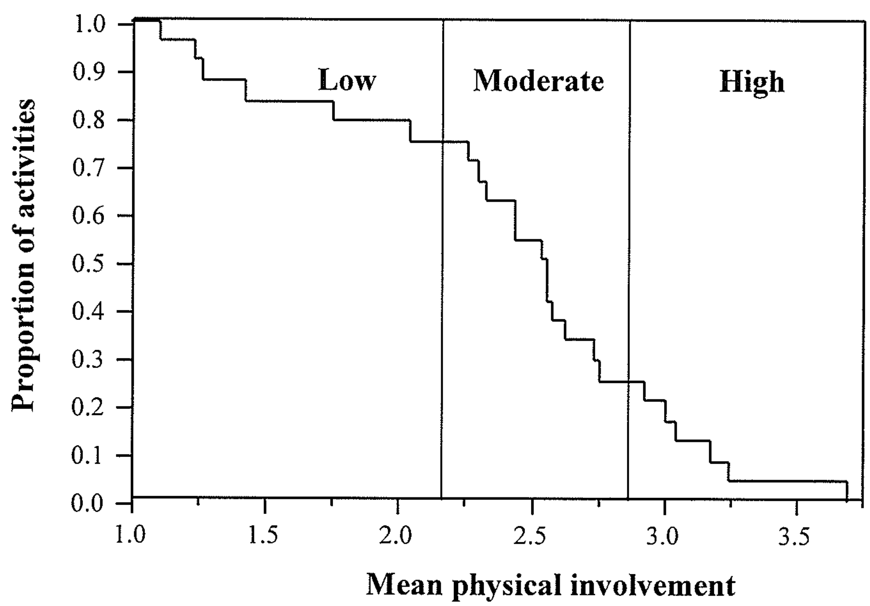



Figure 2. Kaplan-Meier curve demonstrating proportion of activities above mean physical involvement levels.

Because the lowest physical involvement mean possible is 1, 100% of the activities have a mean score of at least 1. As the mean physical involvement scores increase, the proportion of activities above these means decreases. Gaps along the x-axis in the Kaplan-Meier curve were used to establish cut-off points for determining high- and moderate-intensity activities (moderate ranged from 2.26 to 2.76 and high included those at 2.93 and above; see Table 2). A large gap along this axis indicates that two activities have mean scores further apart than a small gap between two activities. The largest gaps along the axis would cluster the activities into different groups and increase the likelihood that the resulting intensity categories would provide activity levels with distinct intensities. It is noteworthy that the resulting categories of intensity provide lists of activities similar to activity measures from recent activity questionnaires for older adults.

Table 2. Categories of activities based on physical involvement*

| High | Moderate | Low |
|---|---|---|
| Yard work (3.70) | Laundry (2.76) | Culture (2.04) |
| Gardening (3.25) | Clubs (2.74) | Games (1.75) |
| Shopping (3.18) | Light housework (2.63) | Radio (1.42) |
| Heavy housework (3.05) | Family (2.58) | Television (1.26) |
| Sport (3.01) | Cooking (2.56) | Phone (1.23) |
| Volunteer (2.93) | Friends (2.56) | Reading (1.10) |
| | Entertainment (2.54) | |
| | Dinner (2.44) | |
| | Social (2.44) | |
| | Collecting (2.33) | |
| | Crafts (2.30) | |
| | Church (2.26) | |

*mean physical involvement in parentheses

Although MET values would have been preferable to help distinguish moderate- and high-intensity activities, they were not used at this point of constructing self-report measures for two reasons. First, some authors have argued that MET values for older adults should be smaller than for younger adults because they perform the same activities at lower intensities (Stewart et al., 2001). However, no compendium of MET values has been produced for older adults. These same authors have suggested modified scores for some activities, but there is no empirical evidence to validate these numbers. Second, many activities from the questionnaire are too broad to be assigned MET values (e.g., sport). Therefore, categories of activity intensities were created with the self-reported physical involvement measure as a substitute for MET values.

There are many different ways to develop a physical activity score. Because there is no standard method, several approaches found in the literature were used to determine the most appropriate method of construction. Scores were derived from multiplying the following variables for each activity in the Leisure Activity Index: frequency, duration, and intensity.

The questionnaire included an 8-point scale to determine frequency of activity participation. The frequency score was used in two ways: 1) the 8-point scale was converted into a 4-point scale, with 1 = 0 and 1, 2 = 2 and 3, 3 = 4 and 5, and 4 = 6 and 7; 2) The 8-point scale was converted into days per year because MET values are multiplied by units of time, such as hours per day or year. Conversion was as follows: 0 (never) = 0 times per year; 1 (less than once a month) = 6; 2 (monthly) = 12; 3 (a few times a month, but not weekly) = 32; 4 (weekly) = 52; 5 (a few times a week, but not daily) = 209; 6 (daily) = 365; 7 (several times a day) = 1095.

Duration was determined by usual duration per activity in hours.

There were three options in terms of determining intensity: not using an intensity score; using MET values from a compendium of physical activity; and using the self-report measure of physical involvement (i.e., the value assigned by the respondent for how physically involved they were in a given activity, not the group mean).

Broad activities (e.g., sport) were provided with MET values from activities that most closely resemble them (Ainsworth, 2002). Although MET values for older adults may be problematic, as noted above, they were used here to provide yet another way of creating a physical activity score that could be compared to other definitions.

In terms of physical involvement, the value assigned by the individual was chosen rather than the group mean because of the variability of intensity between individuals for each activity (e.g., two individuals participating in the same activity but reporting different physical involvement scores).

All possible combinations of scores for high- and moderate-intensity activities (e.g., the sum of (frequency x duration x intensity) for each activity) were produced to determine which combination was more strongly correlated with measures of indirect validation (see legend in Table 3 for a list of all the combinations). For example, the three following variables would be multiplied by each other for each activity in the high-intensity group: the 8-point frequency scale, duration, and no intensity variable. Resulting values are then summed across activities to give the score for this combination.

Respondents would have a score of 0 if they indicated that they did not participate in any of these activities.

Table 3. Spearman correlations of self-report physical activity measures with outcomes

| | Measure | Energy | Physical function | Self-rated health |
|---|---|---|---|---|
| Moderate-intensity activities | fd | 0.355*** | 0.438 | 0.128 |
| | fdm | 0.349*** | 0.434 | 0.133 |
| | frdm | 0.343*** | 0.444 | 0.112 |
| | frd | 0.337*** | 0.445 | 0.103 |
| | fdp | 0.346*** | 0.412 | 0.091 |
| | daydp | 0.312** | 0.327 | 0.194 |
| | daydm | 0.291** | 0.347 | 0.193 |
| | dayd | 0.296** | 0.337 | 0.193 |
| | frdp | 0.334** | 0.410 | 0.063 |
| High-intensity activities | frdp | 0.372*** | 0.563*** | 0.222*** |
| | fdp | 0.368*** | 0.558*** | 0.222*** |
| | frdm | 0.350*** | 0.556*** | 0.178 |
| | frd | 0.346*** | 0.555*** | 0.179 |
| | fdm | 0.348*** | 0.545*** | 0.177 |
| | daydp | 0.370*** | 0.475*** | 0.221*** |
| | fd | 0.337*** | 0.550*** | 0.172 |
| | dayd | 0.355*** | 0.428*** | 0.200*** |
| | daydm | 0.355*** | 0.418*** | 0.192 |

*p<.05, **p<.01, ***p<.001

| | |
|---|---|
| fd | ∑(8-point frequency scale x duration) |
| fdm | ∑(8-point frequency scale x duration x MET) |
| frdm | ∑(4-point frequency scale x duration x MET) |
| frd | ∑(4-point frequency scale x duration) |
| fdp | ∑(8-point frequency scale x duration x physical involvement) |
| daydp | ∑(number of times per year x duration x physical involvement) |
| daydm | ∑(number of times per year x duration x MET) |
| dayd | ∑(number of times per year x duration) |
| frdp | ∑(4-point scale x duration x physical involvement) |

Washburn (2000) distinguishes between direct and indirect validity for physical activity questionnaires. Direct validity can be established by correlating a physical activity measure with physical activity assessed by other methods, such as activity diaries, motion sensors, heart rate monitoring, doubly labeled water, and dietary intake. Indirect validity can be established by correlating a physical activity measure with variables influenced by physical activity, such as resting heart rate, VO2max, muscular strength, body composition, coronary heart disease mortality. Rikli (2000) proposes that measures that are more "functional" could be used to determine indirect validity, such as a person's ability to climb stairs, walk moderate distances, and do one's own shopping and household activities. Measures providing indirect validation for the self-report measures of this thesis included energy, physical functioning, and self-rated health, which have been used to determine indirect validity for several self-report measures of physical activity in older adults (Dubbert, Vander Weg, Kirchner, & Shaw, 2004; Harada et al., 2001; Stewart et al., 2001).

All self-reported physical activity measures were correlated with health measures providing indirect validation (see Table 3). As can be seen in Table 3, the correlations for the moderate-intensity physical activity definitions were between .29 and .36 for energy, .33 and .45 for physical function, and .06 and .19 for self-rated health. Correlations were therefore quite consistent across the different definitions used. The moderate-intensity physical activity measures that were most closely correlated with energy, physical function, and self-rated were the 8-point frequency scale multiplied by duration, the 8-

point frequency scale multiplied by duration and MET values, and the 4-point scale multiplied by duration and MET values.

The correlations for the high-intensity physical activity definitions were between .35 and .37 for energy, .42 and .56 for physical function, and .17 and .22 for self-rated health. As for moderate-intensity physical activity definitions, the correlations were quite similar across measures. Moderate-intensity physical activity measures correlated more highly with physical function than with energy, and more strongly with energy than with self-rated health. The measures of high-intensity physical activity that were most closely correlated with energy, physical function, and self-rated health were the 4-point frequency scale multiplied by duration and physical involvement, the 8-point frequency scale multiplied by duration and physical involvement, and the 4-point frequency scale multiplied by duration and MET values.

Similar correlations were found for moderate- and high-intensity physical activity definitions for energy, but the high-intensity physical activity measures were generally more strongly correlated with physical function and self-rated health than were moderate-intensity measures.

To have consistent definitions for both moderate- and high-intensity self-reported physical activity measures, the same formula was used for both measures. The combination of 8-point frequency multiplied by duration was chosen as the physical activity measure for both moderate- and hard-intensity activity scores because it is the simplest formula and there were only small differences across definitions, indicating similarity between all the definitions. For the distribution of both self-report measures, see Figures 3 and 4.

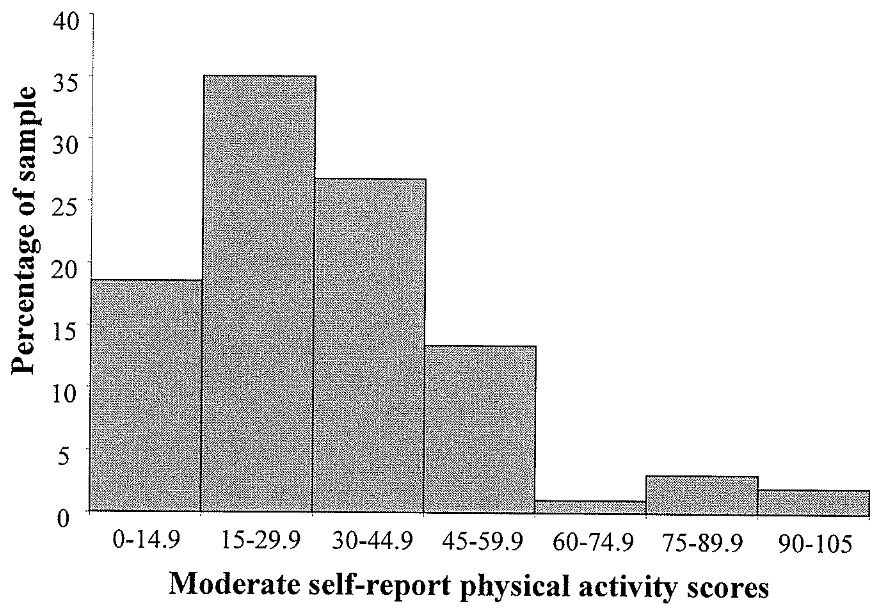



Figure 3. Distribution of moderate-intensity self-report physical activity.

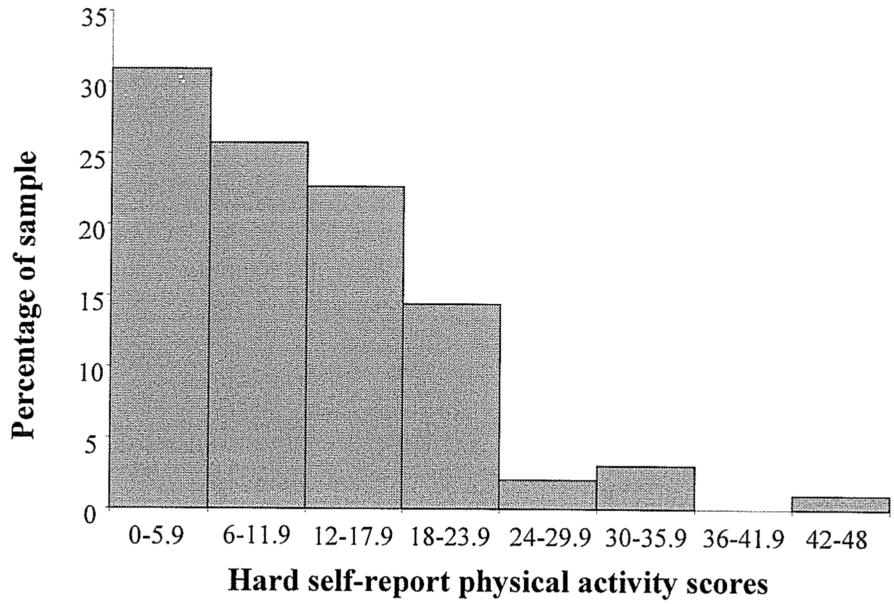



Figure 4. Distribution of high-intensity self-report physical activity.

### *Development of the ActiGraph measures*

In this section, I will discuss how I created three ActiGraph scores. First, I will mention how the data was cleaned. Second, I will describe how I created mean ActiGraph scores. Third, I will describe how I created two other ActiGraph scores: moderate- and vigorous-intensity.

The first step was to put the ActiGraph readings into Excel® files (Microsoft, Redmond, WA). Then, each participant's ActiGraph readings were displayed by charts to provide a visualization of the activity counts per minute over the period the participants wore the ActiGraph and help identify periods where participants either removed the ActiGraph or were sleeping.

The participants were grouped into three categories: 1-, 2-, and 3-day participants. Days were divided into 24-hour periods. One day consisted of a 24-hour period, beginning at the time that the participants first put on the ActiGraph. Some studies exclude time spent sleeping (e.g., Janz, Witt, & Mahoney, 1995; Washburn & Ficker, 1999). However, it was included in this study because most studies do not exclude time spent sleeping and it allows each participant to have similar denominators. In other words, if two participants had the same mean activity count during wake time but have wake times of different lengths, both would have the same score if sleep time were eliminated and different scores if sleep time were included. The participant with more wake time is in reality more active than the other participant, but would only have an ActiGraph score reflecting this if sleep time were included.

Interviewers also indicated at which time participants first put on the ActiGraph. The ActiGraph data that were captured prior to this time were deleted from participants' data. If the participants removed the accelerometer before the designated time, they indicated at which time they removed it. The ActiGraph readings after the time indicated were also removed.

I also eliminated the time when the ActiGraph was temporarily removed (generally for taking a bath or shower) to avoid underestimation of activity level. Because bathing and showering are low-intensity activities, and the oldest-old's activities are generally low-intensity, the elimination of the time the ActiGraph was removed should provide scores similar to scores if it were not removed. The elimination of time when the

ActiGraph was temporarily taken off was accomplished with the help of the questionnaire, on which participants indicated the times at which they removed the ActiGraph (see Appendix B for the questionnaire). These were used as references when looking at the charted ActiGraph readings. If the times the ActiGraph was reported to be off corresponded to the ActiGraph data, the charted ActiGraph readings should be 0. If self-report and the ActiGraph chart did not correspond, the data were eliminated if the ActiGraph chart indicated 0 activity counts.

Studies including accelerometers have involved two types of scores: means (e.g., Brage et al., 2003a; Janz et al., 1995) and proportion of time spent between given cut-off points (e.g., Freedson, Melanson, & Sirard, 1998; Rosenberg, Bull, Braham, Cowper, & Booth, 2002; Trost, Pate, Freedson, Sallis, & Taylor, 2000). Because neither method has been considered preferable over the other, both methods were used in this study. After classifying participants as 1-, 2-, and 3-day participants, the data were averaged to provide mean scores. The 1-day participants had their activity counts over a 24-hour period, indicated by the hours and minutes of the ActiGraph files, averaged to provide one mean day score. The same procedure was used for the 2- and 3-day participants, except that they had two and three 24-hour periods, with means calculated for each 24-hour period. See Figure 5 for the distribution of mean ActiGraph counts of all available data (e.g., mean of two days if there were two days of data).

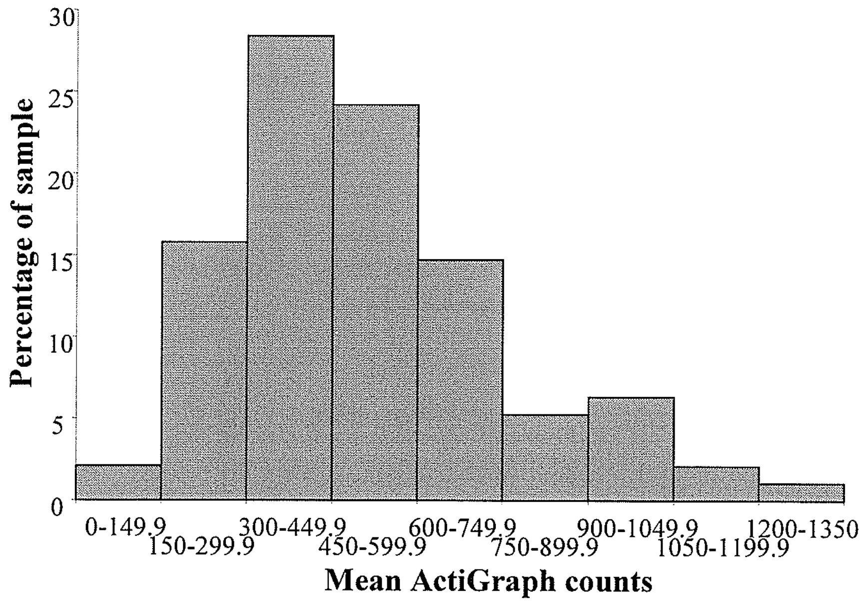



Figure 5. Distribution of mean ActiGraph counts of all days the ActiGraph was worn.

Mean activity counts were also provided for each day of the week. The ActiGraph indicates when it was recording (i.e., date, hour, and minute). The ActiGraph readings were divided into time worn on each day of the week. The ActiGraph readings of those individual days were then averaged to provide mean ActiGraph scores for days of the week.

A second type of ActiGraph score (proportion of time spent in various intensity levels) was calculated for 1-, 2-, and 3-day scores and for each day of the week. Equations have been developed to convert activity counts into units of energy expenditure. Ranges of energy expenditure values have been established to indicate levels of activity intensity (e.g., light, moderate, and vigorous), and the time spent in each of the intensity levels provide ActiGraph scores. Equations used to categorize activity intensity in activity counts for ActiGraphs worn on the wrist explain very little of the variation (i.e., 3%) found in energy expenditure (Brooks et al., 2004; Swartz et al., 2000). In their studies, participants were asked to perform specific activities while wearing an ActiGraph on the wrist and a device measuring their energy expenditure. Mean ActiGraph scores and mean energy expenditure scores for each participant were produced for each activity and entered into a regression model. The ActiGraph scores were entered as a predictor variable and energy expenditure was entered as an outcome measure. Because the equations explain very little of the variation in energy expenditure, they are therefore poor predictors of energy expenditure, which is considered a direct measure of physical activity.

Another issue with the Swartz et al. equation is that it has an intercept of 3 METs. This indicates that 0 activity counts (i.e., no wrist movement) is equal to 3 METs. Three METs is considered hard intensity activity for the oldest-old (USDHHS, 1996). This suggests that the equation would incorrectly categorize the absence of wrist movement with hard intensity activity. Based on a regression plot, several activities with high energy expenditure were related to low activity counts, which provided the high intercept. Therefore, this equation would not be able to identify time spent in daily activities.

The Swartz et al. study did include, however, mean activity counts for a variety of activities, which can be used to create different ActiGraph scores. I assigned each activity included in the Swatz et al. study a MET value provided from a compendium of physical activities (Ainsworth, 2002). The activities and assigned MET values are listed in Table

4. Two activities in the Swartz et al. study were excluded because no MET value could be assigned to them. As a next step, I categorized each activity from the Swartz et al. study as moderate, hard, and very hard based on recommendations by the USDHHS (1996). The USDHHS provides recommendations for categorizing MET values for individuals aged 80 years and older (USDHHS, 1996): very light ≤ 1.0 MET; light, 1.1-1.9; moderate, 2.0-2.9; hard, 3.0-4.25; and very hard > 4.25 (see Table 4).

Table 4. MET values, ActiGraph means, and intensity of activities

| | Mean ActiGraph[a] | MET[b] | Intensity[c] |
|---|---|---|---|
| Power mowing | 1699 | 5.5 | very hard |
| Manual mowing | 1277 | 6 | very hard |
| Golf-pulling clubs | 3219 | 5 | very hard |
| Golf-carrying clubs | 2995 | 5.5 | very hard |
| Double tennis | 5484 | 5 | very hard |
| Softball | 3995 | 5 | very hard |
| Gardening | 4244 | 4 | hard |
| Trimming | 1297 | 4 | hard |
| Raking | 6482 | 4 | hard |
| Vaccuming | 2520 | 3.5 | hard |
| Sweeping and mopping | 3762 | 3.3 | hard |
| Slow walking | 2124 | 3.3 | hard |
| Brisk walking | 3013 | 3.8 | hard |
| Conditioning | 1564 | 3.5 | hard |
| Calisthenics | 6093 | 3.5 | hard |
| Loading and unloading | 5488 | 3 | hard |
| Laundry | 2925 | 2 | moderate |
| Ironing | 2306 | 2.3 | moderate |
| Washing dishes | 2700 | 2.3 | moderate |
| Cooking | 1765 | 2 | moderate |
| Light cleaning | 2624 | 2.5 | moderate |
| Grocery shopping | 1158 | 2.3 | moderate |
| Feeding and grooming animals | 2534 | 2.5 | moderate |
| Playing with animals in the yard | 3522 | 2.8 | moderate |
| Caring for children | 2464 | 2.5 | moderate |
| Playing with children in the yard | 4961 | 2.8 | moderate |

[a] Obtained from Swartz et al. 2000

[b] Obtained from Ainsworth, 2002

[c] Obtained from USDHHS, 1996

The activity counts derived by Swartz et al. were then averaged within each category (moderate, hard, and very hard). The means were 2695.9, 3658.7, and 3111.5 for moderate, hard, and very hard activities respectively (see Table 5). The mean for very hard was lower than hard and was therefore disregarded. The median between the means of moderate and hard activities (3177.5) was considered the cut-off between the moderate- and hard-intensity levels. The difference between the moderate mean and the cut-off (3658.7 – 2695.9 = 481.4) was subtracted from the moderate mean (i.e., 2695.9 – 481.4) to provide the cut-off between light and moderate intensities (2214). The same value was added to the hard mean to provide the cut-off between hard and very hard intensity activities (i.e., 3658.7 + 481.4 = 4140). Very hard activity was considered activity counts above 4140. For a visual representation of the previous means and the resulting cut-off values, see Figure 6.

Table 5. Cut-off points for ActiGraph measures

| Intensity | ActiGraph mean | Median* | Cut-off points** Minimum | Maximum |
|---|---|---|---|---|
| Moderate | 2695.9 | } 3177.5 | 2214 | 3177 |
| Hard | 3658.7 | | 3178 | 4140 |
| Very hard | 3111.5 | | 4141+ | |

*The median is 481.4 activity counts from the moderate mean and from the hard mean

**Minimum and maximum were calculated as mean ± 481.4 for moderate and hard

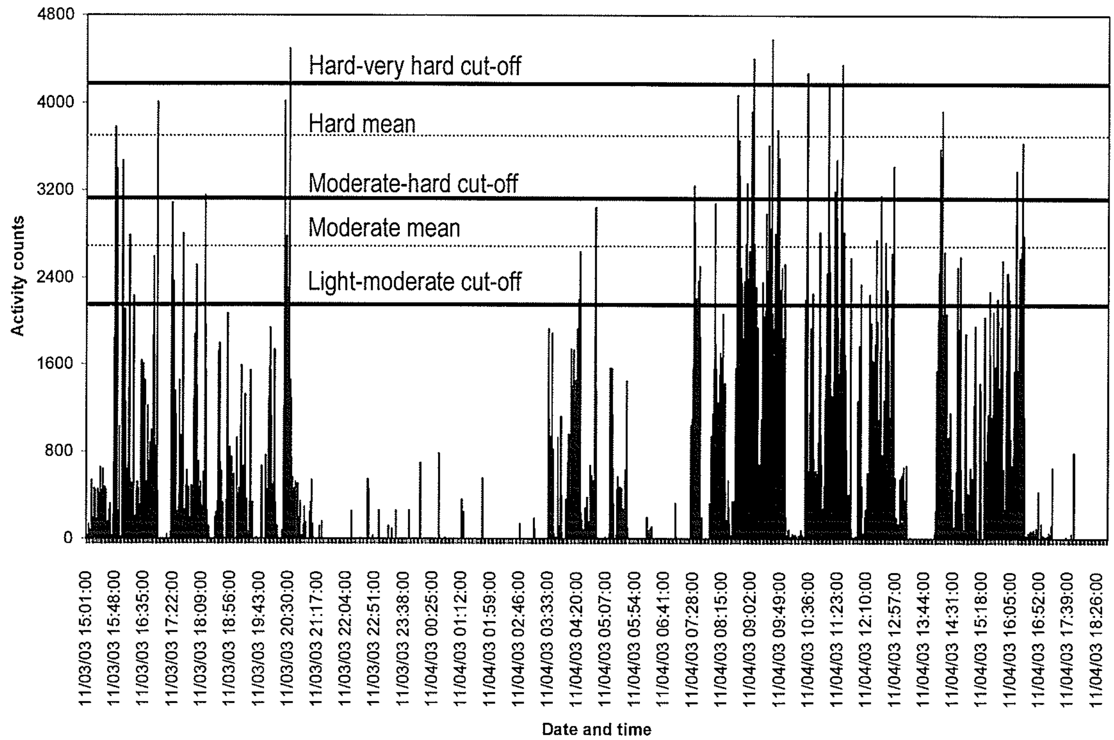



Figure 6. Activity count means and resulting cut-off values derived from Swartz et al. illustrated in a participant's ActiGraph data output.

Because 3 METs and above has been used as a physical activity measure (Stewart et al., 2001) and that this group spent very little time in the very hard category (a mean 6.34 minutes with a standard deviation of ± 10.66 vs. 27.79 minutes ± 28.66 in the hard category), percentage of time spent at hard and very hard intensities were combined (i.e., proportion of time at 3178+ was included as a measure of high/very hard intensity physical activity) and hereafter referred to as vigorous intensity. See Figures 7 and 8 for the distribution of moderate and vigorous ActiGraph scores. Figure 7 demonstrates the distribution of percentage of time spent between 2214 and 3177 activity counts (i.e., time spent between these two values divided by the total time), whereas Figure 8 demonstrates the distribution of percentage of time spent at 3178 activity counts and above.

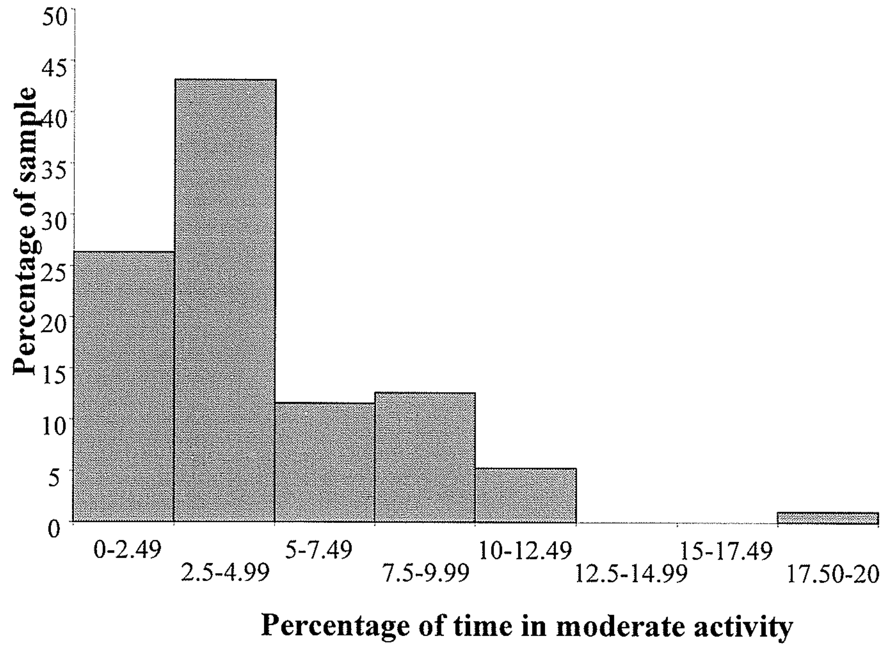



Figure 7. Distribution of moderate-intensity Actigraph measure.

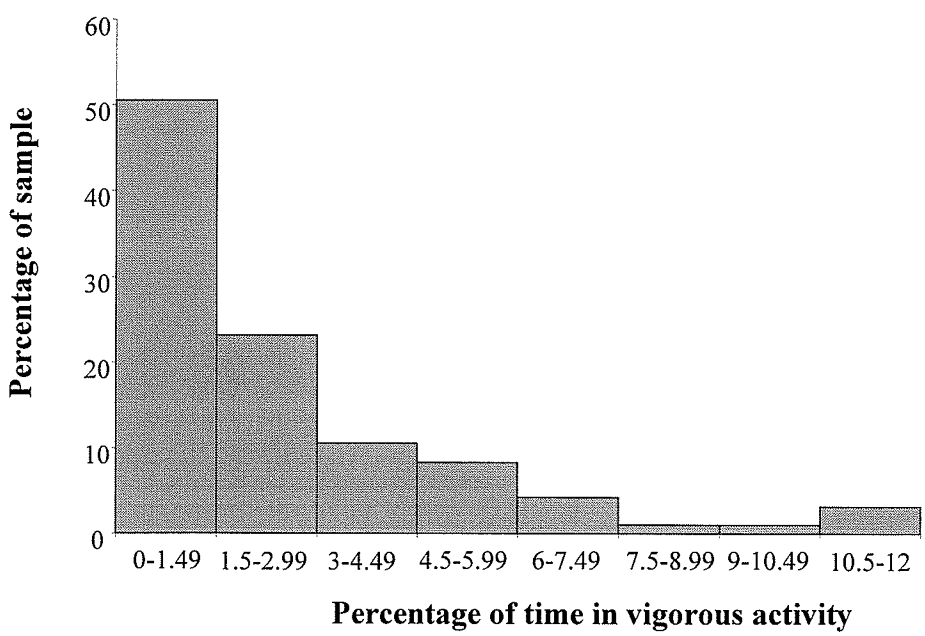



Figure 8. Distribution of vigorous-intensity ActiGraph measure.

**Objective 1 – Compliance of wearing an ActiGraph**

The following results are derived from the 50 participants who were asked to wear an ActiGraph for three days. Figure 9 shows the number of hours participants wore the ActiGraph. Some participants refused to wear the ActiGraph, which is reflected in the graph as slightly less than 100% of participants wearing the ActiGraph at 0 hours. The proportion of participants who wore the ActiGraph gradually declined for the first 50 hours. At 24 hours, over 90% of individuals still wore the ActiGraph, about 80% at 48 hours, and 70% after 72 hours.

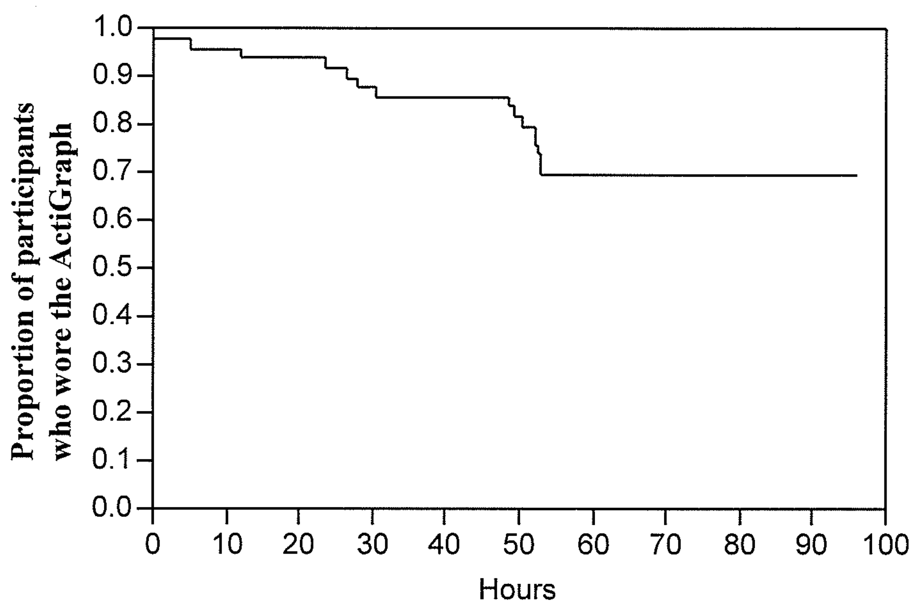



Figure 9. Number of hours ActiGraph was worn: All participants

When subgroups were compared, female participants showed a slightly different pattern than male participants (see Figure 10). The proportion of female participants who wore the ActiGraph decreased gradually from 0 to 60 hours. For male participants a decrease did not start until 30 hours, and was not substantial until 50 hours.

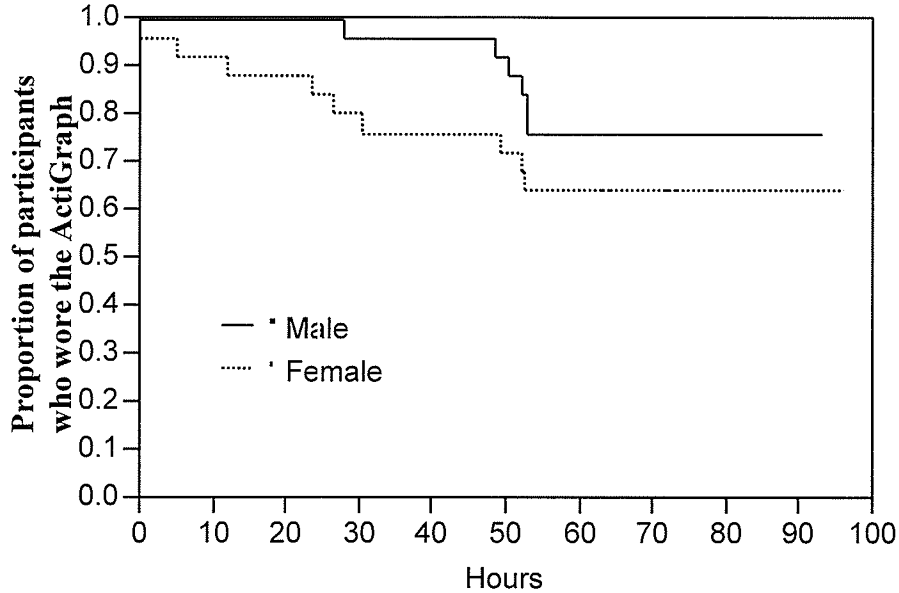



Figure 10. Number of hours ActiGraph was worn by gender

A logistic regression analysis was conducted to detect differences in compliance, defined here as having worn the ActiGraph 63 hours or more, between genders. Gender was included as the only predictor variable. The analysis indicated that men and women did not significantly differ in rates of compliance (see Table 6).

Table 6. Logistic regression models including predictors of participants' compliance (N = 49)†

| Predictors | Odds ratio | Confidence limits |
|---|---|---|
| Age | 0.99 | 0.88 - 1.21 |
| Gender | 1.78 | 0.52 - 6.09 |
| Depression | 1.00 | 0.74 - 1.34 |
| Happiness | 0.57 | 0.04 - 8.03 |
| Physical function | 1.02 | 0.30 - 3.43 |
| Energy | 1.06 | 0.65 - 1.74 |
| Self-rated health | 1.62 | 0.73 - 3.60 |

*p<.05

†Each predictor was entered in separate logistic regression models

Figure 11 shows the number of hours the ActiGraph was worn by younger (80 to 84) and older participants (85 to 101). The proportion of individuals in either age group who wore the ActiGraph gradually decreased until 50 hours. A logistic regression analysis, with age as the only predictor, indicated that the two age groups did not significantly differ in rates of compliance (see Table 6).

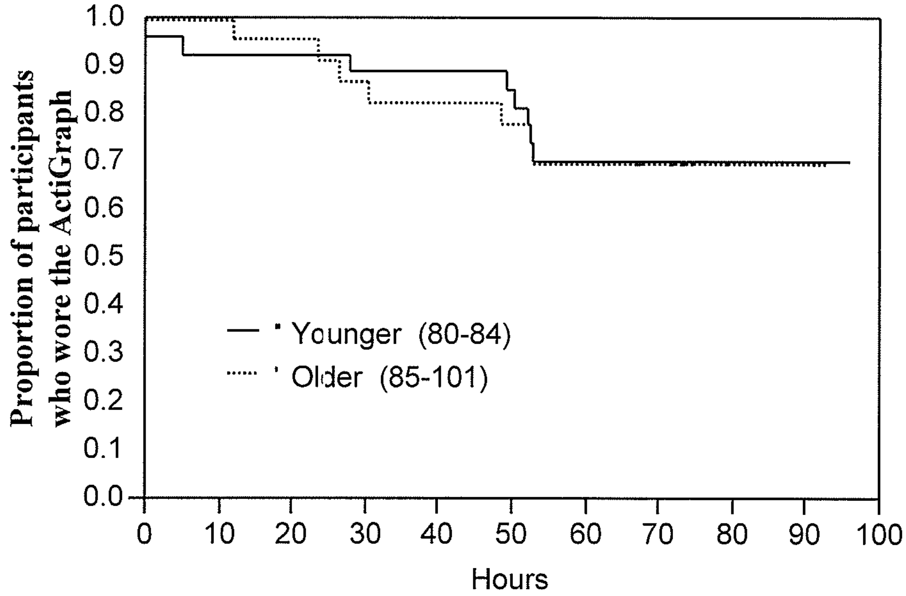



Figure 11. Number of hours ActiGraph was worn by age group.

Compliance was also not related to health and well-being measures when each measure was entered into separate logistic regression models (self-rated health, physical function, energy, CESD, and SHARP; see Table 6).

**Objective 2 – Examining the stability of ActiGraph readings**

Table 7 shows results from the regressions, Pearson correlations, and paired t-tests that were computed to examine the stability of ActiGraph counts for Day 1 versus Day2, Day 1 versus Day 3, and Day 2 versus Day 3, respectively. Separate regressions, correlations, and t-tests were run for five groups, the total sample, women, men, and younger (aged 80 to 84) versus older individuals (aged 85 or older). Moreover, separate analyses were run for three measures: mean ActiGraph counts, counts that fell within the moderate activity range, and counts that fell into the vigorous activity range.

Mean ActiGraph counts were generally very stable for all comparisons. This is evidenced by the fact that all intercepts and most slopes from the regressions did not significantly deviate from 0 and 1. Only three slopes deviated significantly from 1: for the day-1 versus Day-2, significant slopes emerged for the overall sample, male, and older age groups. All Pearson correlations were significant and varied from .82 to .97, indicating that mean ActiGraph scores were strongly associated to each other during the three-day period. All t-tests were non-significant, which provides further support for the conclusion that mean ActiGraph scores were stable across the three days.

Similar results were found for the moderate intensity measure. Only one intercept significantly deviated from 0 for the moderate intensity measure (i.e., younger age group for Day-1 versus Day-2 comparisons; see Table 7) and none of the slopes significantly deviated from 1, indicating that the proportion of time spent in moderate physical activities levels was stable across the three-day period. All Pearson correlations were significant and varied from .83 to .94. All t-tests were non-significant except for the subgroups of women's Day-1 versus Day-2 comparisons and older participants' Day-1 versus Day-3 comparisons.

Table 7. Analyses for stability of ActiGraph scores from 1 to 3 days

| | | Group† | df | Intercept | Slope | Correlation | T-test |
|---|---|---|---|---|---|---|---|
| Mean activity level | Day 1 vs Day 2 | Overall | 41 | 52.58 | 0.85* | .91*** | 1.44 |
| | | Women | 17 | 5.21 | 0.95 | .95*** | 1.24 |
| | | Men | 23 | 81.02 | 0.79* | .88*** | 0.95 |
| | | Older | 17 | 92.28 | 0.71* | .83*** | 0.88 |
| | | Younger | 23 | 61.49 | 0.86 | .90*** | 1.13 |
| | Day 1 vs Day 3 | Overall | 26 | 16.61 | 0.96 | .89*** | 0.16 |
| | | Women | 11 | 25.95 | 0.97 | .82*** | 0.17 |
| | | Men | 14 | 6.57 | 0.96 | .97*** | 0.85 |
| | | Older | 9 | 26.37 | 0.89 | .95*** | 1.01 |
| | | Younger | 16 | 42.07 | 0.94 | .85*** | 0.15 |
| | Day 2 vs Day 3 | Overall | 26 | -10.64 | 1.04 | .89*** | 0.41 |
| | | Women | 11 | 11.81 | 0.99 | .87*** | 0.27 |
| | | Men | 14 | -30.11 | 1.07 | .90*** | 0.31 |
| | | Older | 9 | 4.29 | 0.93 | .84*** | 0.65 |
| | | Younger | 16 | 24.07 | 1.01 | .87*** | 0.87 |
| Moderate activity level | Day 1 vs Day 2 | Overall | 41 | 0.55 | 0.93 | .94*** | 1.55 |
| | | Women | 17 | 0.79 | 0.96 | .94*** | 2.14* |
| | | Men | 23 | 0.42 | 0.90 | .95*** | 0.08 |
| | | Older | 17 | 0.23 | 0.93 | .89*** | 0.39 |
| | | Younger | 23 | 1.12* | 0.88 | .93*** | 1.54 |
| | Day 1 vs Day 3 | Overall | 26 | 0.77 | 0.90 | .88*** | 0.88 |
| | | Women | 11 | 0.99 | 0.87 | .84*** | 0.60 |
| | | Men | 14 | 0.55 | 0.93 | .93*** | 0.67 |
| | | Older | 9 | 0.19 | 1.03 | .87*** | 2.39* |
| | | Younger | 16 | 1.24 | 0.84 | .83*** | 0.59 |
| | Day 2 vs Day 3 | Overall | 26 | 0.50 | 0.93 | .90*** | 0.56 |
| | | Women | 11 | 0.53 | 0.89 | .89*** | 0.02 |
| | | Men | 14 | 0.36 | 0.99 | .92*** | 0.92 |
| | | Older | 9 | 0.52 | 0.97 | .83*** | 1.50 |
| | | Younger | 16 | 0.35 | 0.95 | .87*** | 0.02 |
| Vigorous activity level | Day 1 vs Day 2 | Overall | 41 | 0.15 | 1.13 | .90*** | 1.95 |
| | | Women | 17 | 0.19 | 1.12 | .97*** | 2.09 |
| | | Men | 23 | 0.10 | 1.15 | .83*** | 1.22 |
| | | Older | 17 | 0.01 | 1.25 | .85*** | 1.09 |
| | | Younger | 23 | 0.22 | 1.11 | .91*** | 1.61 |
| | Day 1 vs Day 3 | Overall | 26 | 0.62 | 0.72*** | .89*** | 0.67 |
| | | Women | 11 | 0.84 | 0.58*** | .87*** | 0.39 |
| | | Men | 14 | 0.01 | 0.95 | .95*** | 0.73 |
| | | Older | 9 | 0.08 | 1.03 | .94*** | 0.64 |
| | | Younger | 16 | 0.90 | 0.66*** | .99*** | 0.88 |
| | Day 2 vs Day 3 | Overall | 26 | 0.91* | 0.54*** | .85*** | 1.39 |
| | | Women | 11 | 0.77 | 0.53*** | .89*** | 0.91 |
| | | Men | 14 | 1.02 | 0.54*** | .82*** | 1.01 |
| | | Older | 9 | 0.25 | 0.81 | .91*** | 0.14 |
| | | Younger | 16 | 1.29* | 0.48*** | .89*** | 1.40 |

*p<.05, **p<.01, ***p<.005

†Separate analyses were calculated for each the 5 groups

Older = 85 or older; Younger = 80 to 84

Vigorous intensity levels were also quite stable, but less so than mean ActiGraph counts and moderate intensity scores. Two intercepts significantly deviated from 0 (i.e., for all participants and younger participants for Day-2 versus Day-3 comparisons; see Table 7). Seven of 15 slopes significantly differed from 1 for Day-1 versus Day-3 and Day-2 versus Day-3 comparisons. None of the slopes from Day-1 versus Day-2 comparisons significantly deviated from 1. All Pearson correlations were significant and varied from .82 to .99. All t-tests were non-significant.

Group means and standard deviations for mean ActiGraph scores and proportion of time in moderate and vigorous activity for each day of the week were calculated to examine a possible day-of-the-week effect. Group means and standard deviations were obtained from the data provided by those who were asked to wear the ActiGraph for three days. One participant did not respond to the questions in the questionnaire that were used as predictors in this analysis, which resulted in a sample of 49 participants. Table 8 indicates that group means for mean ActiGraph scores vary from 478 activity counts on Thursday to 562 activity counts on Sunday. The standard deviations were wide, indicating that it is unlikely for there to be a day-of-the-week effect with mean ActiGraph scores. The proportion of time spent in moderate and vigorous activity also indicated similar group means between days and wide standard deviations. Therefore, it is also unlikely for there to be a day-of-the-week effect with moderate and vigorous ActiGraph scores.

Table 8. Group means* for mean ActiGraph scores and proportion of time in moderate and vigorous activity for each day of the week

| Day | n | Mean | Moderate | Vigorous |
|---|---|---|---|---|
| Sunday | 13 | 562 (280) | 4.54 (2.91) | 2.48 (2.33) |
| Monday | 19 | 544 (317) | 4.63 (4.39) | 2.64 (2.48) |
| Tuesday | 25 | 489 (221) | 3.90 (3.24) | 2.46 (2.32) |
| Wednesday | 32 | 508 (253) | 4.17 (3.25) | 2.55 (2.87) |
| Thursday | 30 | 478 (251) | 3.86 (3.09) | 2.42 (2.63) |
| Friday | 25 | 516 (280) | 4.53 (3.52) | 2.67 (3.31) |
| Saturday | 19 | 490 (274) | 4.63 (3.86) | 2.51 (3.34) |

*standard deviations shown in parentheses

Spearman correlations were used next to examine the relationship between ActiGraph scores of participants who wore the ActiGraph for three days and measures of depression and happiness, in order to examine the similarity of these relationships over the three-day period. Correlations between mean ActiGraph scores and well-being were generally similar between days (see Table 9), although correlations were stronger for happiness than depression (.00 to .10 for depression and .28 to .34 for happiness). The correlations for moderate ActiGraph scores were less similar, with correlations varying between -.21 to .09 for depression and between .13 to .41 for happiness. Correlations for vigorous ActiGraph scores were similar between days, ranging from .01 to .09 when correlated with depression and from .30 to .38 when correlated with happiness.

Table 9. Spearman correlations between ActiGraph scores of individual days or overall period to depression and happiness (N=27)

| | | Depression | Happiness |
|---|---|---|---|
| Mean ActiGraph counts | Day 1 | .10 | .28 |
| | Day 2 | .00 | .30 |
| | Day 3 | .01 | .28 |
| | Overall | .03 | .34 |
| Moderate ActiGraph | Day 1 | -.14 | .30 |
| | Day 2 | .03 | .37 |
| | Day 3 | .09 | .41* |
| | Overall | -.21 | .13 |
| Vigorous ActiGraph | Day 1 | .01 | .30 |
| | Day 2 | .07 | .38 |
| | Day 3 | .09 | .34 |
| | Overall | .03 | .33 |

*p<.05

**Objective 3 – Examining the relationship between physical activity measures**

To address Objective 3, Spearman correlations were first calculated to determine the association between physical activity measures. Correlations between activity measures indicated that ActiGraph scores were more highly correlated to each other (.44 to .81) than were self-report measures to each other (.44 to .62; see Table 10). This indicates that the self-report measures may be more dissimilar to each other than the ActiGraph scores are to each other.

Table 10. Spearman correlations between activity measures (N = 91)

| | Single-item measure | Moderate self-report | Hard self-report | Mean ActiGraph counts | Moderate ActiGraph |
|---|---|---|---|---|---|
| Moderate self-report | .445*** | | | | |
| Hard self-report | .440*** | .621*** | | | |
| Mean ActiGraph counts | .268* | .183 | .350*** | | |
| Moderate ActiGraph | -.094 | -.163 | .043 | .440*** | |
| Vigorous ActiGraph | .225* | .017 | .296** | .811*** | .736*** |

*p<.05, **p<.01, ***p<.001

When examining correlations across types of measures, the single-item activity scale was more strongly correlated with mean ActiGraph counts than moderate-intensity and vigorous ActiGraph scores (.27 versus -.09 and .23). The moderate self-report measure was also more strongly correlated with mean ActiGraph scores than with moderate ActiGraph scores and vigorous ActiGraph counts (.18 versus -.16 and .02). Similarly, the hard self-report measure was more strongly correlated with the mean ActiGraph score than the moderate and vigorous (.35 versus .04 and .30).

Mean ActiGraph counts were less strongly correlated with the single-item activity measure than with the hard self-report measure, and the weakest correlation was with the moderate self-report measure (.27 versus .35 and .18). Moderate ActiGraph scores were more strongly correlated with the single-item and the moderate self-report measures than the hard self-report measure; however two of the correlations were negative (-.09 versus -.16 and .04). Vigorous ActiGraph scores were most strongly correlated with the hard self-report measure, followed by the single-item activity measure and the moderate self-report measure (.30 versus .23 and .02).

Thus, the high-intensity measures were more strongly correlated with each other than with measures of different intensity, whereas the moderate-intensity measures were negatively correlated to each other. This indicates that the greatest congruence is between the high-intensity self-report and ActiGraph scores.

To further explore the association between the high-intensity self-report physical activity measure and vigorous ActiGraph scores, I then created tertiles for both measures and calculated a weighted kappa. Table 11 provides a 3x3 table illustrating the distribution of both activity measures. Forty of 91 participants' scores are congruent, which indicates that 44% of the scores correspond to the same intensity for both measures. The weighted kappa was 0.197, indicating poor agreement between both measures.

Table 11. Counts of participants in each combination of self-report and ActiGraph tertiles

| | | Self-report | | |
|---|---|---|---|---|
| | | Low | Moderate | High |
| ActiGraph | Low | 13 | 10 | 6 |
| | Moderate | 7 | 13 | 11 |
| | High | 7 | 10 | 14 |

Weighted kappa=0.197

**Objective 4 – Comparing the predictive validity of physical activity measures**

I computed a series of regressions. In the first set of analyses, the three self-report measures of physical activity and three ActiGraph measures (all dichotomized) were regressed on depression and happiness, both individually and while controlling for possible confounders (see Table 12). When activity measures were entered alone in separate regression models, only the self-report measures were significantly related to depression. However, only the hard self-report activity measure remained significant when including control variables. When these same binary activity measures were entered alone in separate regression models to predict happiness, the single-item, hard self-report, and vigorous ActiGraph measures were significant. None of the measures remained significant when including control variables.

Table 12. Results of multiple regressions analyses including binary physical activity measures (N=91)

| | | Depression | | Happiness | |
|---|---|---|---|---|---|
| | | Model A | Model B | Model A | Model B |
| | | β | β | β | β |
| Self-reported activity | **Single-item measure** | 0.29** | 0.11 | 0.34*** | 0.09 |
| | Perceived control | / | 0.41*** | / | 0.41*** |
| | Self-rated health | / | / | / | 0.20* |
| | **Moderate self-report** | 0.22** | 0.08 | 0.18 | 0.02 |
| | Perceived control | / | 0.48*** | / | 0.44*** |
| | Self-rated health | / | / | / | 0.22* |
| | Age | / | 0.22* | / | / |
| | Living arrangements | / | 0.19* | / | / |
| | **Hard self-report** | 0.35*** | 0.24* | 0.30** | 0.07 |
| | Perceived control | / | 0.40*** | / | 0.42*** |
| | Self-rated health | / | / | / | 0.21* |
| | Age | / | 0.23* | / | / |
| ActiGraph measures | **Mean ActiGraph counts** | 0.11 | -0.02 | 0.14 | -0.01 |
| | Perceived control | / | 0.44*** | / | 0.45*** |
| | Self-rated health | / | / | / | 0.23* |
| | **Moderate ActiGraph** | 0.09 | 0.01 | 0.20 | 0.08 |
| | Perceived control | / | 0.43*** | / | 0.44*** |
| | Self-rated health | / | | / | 0.23* |
| | **Vigorous ActiGraph** | 0.20 | 0.03 | 0.28** | 0.07 |
| | Perceived control | / | 0.42*** | / | 0.42*** |
| | Self-rated health | / | / | / | 0.23* |

*p<.05, **p<.01, ***p<.001

Model A: model contains only one physical activity measure

Model B: model contains one physical activity measure and all control variables found to be significant

β=standardized regression coefficient

In a second set of regressions, activity measures were entered as tertiles, with tertile 1 treated as the reference category to which the other tertiles were compared (see Table 13). Only the single-item, hard self-report, and vigorous ActiGraph measures were significantly related to depression. None of the relationships remained significant when including control variables. If the same tertiles were entered alone in separate regression models to predict happiness, the mean single-item, hard self-report, mean ActiGraph counts, and vigorous ActiGraph measures had significant effects, although for the vigorous ActiGraph measure only the third tertile differed significantly from the first tertile. However, none of the relationships remained significant when including control variables.

Table 13. Results of multiple regression analyses including tertile physical activity measures (N=91)†

| | | Depression | | Happiness | |
|---|---|---|---|---|---|
| | | Model A | Model B | Model A | Model B |
| | | β | β | β | β |
| | **Single-item measure 2nd tertile** | 0.29** | 0.14 | 0.33** | 0.12 |
| | **Single-item measure 3rd tertile** | 0.22* | 0.01 | 0.28** | 0.00 |
| | Perceived control | / | 0.43*** | / | 0.44*** |
| | Self-rated health | / | / | / | 0.20* |
| | **Moderate self-report 2nd tertile** | 0.11 | 0.01 | 0.06 | 0.04 |
| | **Moderate self-report 3rd tertile** | 0.17 | 0.05 | 0.19 | 0.02 |
| Self-reported activity | Perceived control | / | 0.49*** | / | 0.44*** |
| | Self-rated health | / | / | / | 0.22* |
| | Age | / | 0.22* | / | / |
| | Living arrangements | / | 0.20* | / | / |
| | **Hard self-report 2nd tertile** | 0.06 | -0.10 | 0.26* | 0.00 |
| | **Hard self-report 3rd tertile** | 0.27* | 0.09 | 0.34** | 0.06 |
| | Perceived control | / | 0.49*** | / | 0.42*** |
| | Self-rated health | / | / | / | 0.22* |
| | Age | / | 0.20* | / | / |
| | **Mean ActiGraph counts 2nd tertile** | 0.19 | -0.01 | 0.29* | 0.02 |
| | **Mean ActiGraph counts 3rd tertile** | 0.16 | -0.01 | 0.28* | 0.09 |
| | Perceived control | / | 0.43*** | / | 0.43*** |
| | Self-rated health | / | / | / | 0.24* |
| | **Moderate ActiGraph 2nd tertile** | 0.10 | 0.10 | 0.21 | 0.20 |
| ActiGraph measures | **Moderate ActiGraph 3rd tertile** | 0.04 | -0.05 | 0.16 | 0.03 |
| | Perceived control | / | 0.45*** | / | 0.47*** |
| | Self-rated health | / | / | / | 0.23* |
| | **Vigorous ActiGraph 2nd tertile** | 0.26* | 0.13 | 0.17 | 0.01 |
| | **Vigorous ActiGraph 3rd tertile** | 0.28* | 0.10 | 0.34** | 0.10 |
| | Perceived control | / | 0.39*** | / | 0.42*** |
| | Self-rated health | / | / | / | 0.23* |

*p<.05, **p<.01, ***p<.001

†first tertile is the reference group

Model A: model contains only the two highest tertiles of physical activity measures

Model B: model contains the two highest tertiles of physical activity all control variables found to be significant

β=standardized regression coefficient

When activity measures of similar intensities were included in the same regression models (see Table 14), the self-report measures were generally more strongly related to well-being than the ActiGraph measures. When the binary single-item scale and mean ActiGraph counts were entered together in the same regression models, the single-item scale was significantly related to depression and happiness, whereas mean ActiGraph counts were not. However, the single-item scale was no longer significantly related to either well-being measure when control variables were included.

Table 14. Results of multiple regression analyses including binary physical activity measures of similar intensities (N=91)

| | Depression | | | Happiness | | |
|---|---|---|---|---|---|---|
| | Model A | Model B | Model C | Model A | Model B | Model C |
| | β | β | β | β | β | β |
| **Single-item measure** | 0.29** | 0.28** | 0.14 | 0.34*** | 0.34** | 0.13 |
| **Mean ActiGraph** | 0.11 | 0.06 | -0.02 | 0.14 | 0.09 | -0.02 |
| Perceived control | / | / | 0.38*** | / | / | 0.41*** |
| Self-rated health | / | / | / | / | / | 0.22* |
| **Moderate self-report** | 0.22** | 0.23* | 0.11 | 0.18 | 0.19 | 0.06 |
| **Moderate ActiGraph** | 0.09 | 0.13 | 0.03 | 0.20 | 0.23* | 0.1 |
| Perceived control | / | / | 0.40*** | / | / | 0.42*** |
| Self-rated health | / | / | / | / | / | 0.23* |
| **Hard self-report** | 0.35*** | 0.32** | 0.25* | 0.30** | 0.22* | 0.06 |
| **Vigorous ActiGraph** | 0.20 | 0.07 | 0.02 | 0.28** | 0.19 | 0.05 |
| Perceived control | / | / | 0.39*** | / | / | 0.40*** |
| Self-rated health | / | / | / | / | / | 0.23* |
| Age | / | / | 0.24* | / | / | / |

*p<.05, **p<.01, ***p<.001

Model A: physical activity measures entered alone in separate models

Model B: model contains both physical activity measures

Model C: model contains both physical activity measures and all control variables found to be significant

β=standardized regression coefficient

When the binary moderate self-report and ActiGraph measures were included together in the same regression models, the self-report measure was significantly related to depression but not happiness, whereas the ActiGraph measure was not significantly related to depression, but significantly related to happiness. However, both significant relationships became non-significant when including control variables.

When the binary hard self-report and vigorous ActiGraph measures were included in the same regression models, the self-report measure was significantly related to depression and happiness, whereas the ActiGraph measure was not. The significant relationship between hard self-report and happiness did not remain when including control variables, but the significant relationship between hard self-report and depression did remain.

Similar results were found when the previous analyses were repeated with tertile measures of physical activity (see Table 15). The single-item measure was significantly related to depression and happiness when entered with the mean ActiGraph counts, but the relationships were non-significant when including control variables. Neither moderate self-report nor ActiGraph measures were significantly related to depression and happiness when both activity measures were included in the same model, but the ActiGraph measure became significantly related to happiness when including control variables.

Neither hard self-report or vigorous ActiGraph measures were significantly related to depression when entered into the same regression model, but they were both significantly related to happiness when entered into the same model. However, that significant relationship did not remain when including control variables.

Table 15. Results of multiple regression analyses including tertile physical activity measures of similar intensities (N=91)†

| | Depression | | | Happiness | | |
|---|---|---|---|---|---|---|
| | Model A | Model B | Model C | Model A | Model B | Model C |
| | β | β | β | β | β | β |
| **Single-item measure 2nd tertile** | 0.29** | 0.28* | 0.19 | 0.33** | 0.29* | 0.16 |
| **Single-item measure 3rd tertile** | 0.22* | 0.18 | 0.03 | 0.28** | 0.24* | 0.02 |
| **Mean ActiGraph counts 2nd tertile** | 0.19 | 0.11 | -0.04 | 0.29* | 0.19 | -0.01 |
| **Mean ActiGraph counts 3rd tertile** | 0.16 | 0.08 | -0.03 | 0.28* | 0.19 | 0.07 |
| Perceived control | / | / | 0.41*** | / | / | 0.42*** |
| Self-rated health | / | / | / | / | / | 0.23* |
| **Moderate self-report 2nd tertile** | 0.11 | 0.05 | -0.02 | 0.06 | -0.03 | -0.14 |
| **Moderate self-report 3rd tertile** | 0.17 | 0.15 | -0.04 | 0.19 | 0.16 | -0.06 |
| **Moderate ActiGraph 2nd tertile** | 0.10 | 0.07 | 0.11 | 0.21 | 0.19 | 0.22* |
| **Moderate ActiGraph 3rd tertile** | 0.04 | 0.07 | -0.06 | 0.16 | 0.20 | 0.02 |
| Perceived control | / | / | 0.46*** | / | / | 0.47*** |
| Self-rated health | / | / | / | / | / | 0.24* |
| **Hard self-report 2nd tertile** | 0.06 | -0.01 | -0.18 | 0.26* | 0.22 | 0.03 |
| **Hard self-report 3rd tertile** | 0.27* | 0.19 | 0.06 | 0.34** | 0.27* | 0.10 |
| **Vigorous ActiGraph 2nd tertile** | 0.26* | 0.23 | 0.14 | 0.17 | 0.11 | 0.00 |
| **Vigorous ActiGraph 3rd tertile** | 0.28* | 0.23 | 0.07 | 0.34** | 0.28* | 0.09 |
| Perceived control | / | / | 0.30* | / | / | 0.39*** |
| Self-rated health | / | / | 0.25* | / | / | 0.24* |

*p<.05, **p<.01, ***p<.001

†first tertile is the reference group

Model A: physical activity measures entered alone in separate models

Model B: model contains both physical activity measures

Model C: model contains both physical activity measures and all control variables found to be significant

β=standardized regression coefficient

Another method of examining the relationship between tertiles of high-intensity activities and well-being was with ANOVA analyses. The results demonstrate that when self-reported physical activity and ActiGraph measures were entered in separate ANOVA models with depression as an outcome, only the ActiGraph measure was significantly related to depression (see Table 16). When both measures were included in the same ANOVA model, both were non-significantly related to depression. The interaction effect was also not significant.

Table 16. Results for ANOVAs between physical activity measures and well-being

| | Depression | | | Happiness | | |
|---|---|---|---|---|---|---|
| | Model A | Model B | Model C | Model A | Model B | Model C |
| | F-ratio | F-ratio | F-ratio | F-ratio | F-ratio | F-ratio |
| Hard Self-report | 2.72 | 1.63 | 2.67 | 4.04* | 2.01 | 2.57 |
| Vigorous ActiGraph | 3.75* | 2.82 | 2.08 | 4.71* | 3.31* | 3.12* |
| Self-report x ActiGraph | / | / | 1.45 | / | / | 1.05 |

*p<.05, **p<.01, ***p<.001

Model A: physical activity measures entered in separate ANOVA models

Model B: both physical activity measures entered in the same ANOVA model

Model C: both physical activity measures entered in the same ANOVA model with an interaction term

For happiness, significant effects emerged both for self-reported physical activity and Actigraph measures that were entered in separate ANOVA models (see Table 16). When both measures were included in the same ANOVA model, only the Actigraph measure was significantly related to happiness. When an interaction term was included in the previous model, the interaction term was not significantly related to happiness, but the ActiGraph measure remained significantly related to the outcome.

Lastly, regressions were run in which the same type of activity measures were included in the same models (e.g., moderate and vigorous ActiGraph) to examine the unique relationships between activity intensities and well-being when controlling for both levels of activity intensity (see Table 17). The results indicated that the higher-intensity measures were more likely to be significantly related to well-being. When binary moderate and hard self-report activity measures were included in the same model, the hard self-report measure was significantly related to depression and happiness (see Table 17). Although the significant relationship between hard self-report and depression remained when including control variables, the significant relationship between hard self-report and happiness did not.

Table 17. Results of multiple regression analyses including binary physical activity measures of the same type (N=91)

| | Depression | | | Happiness | | |
|---|---|---|---|---|---|---|
| | Model A | Model B | Model C | Model A | Model B | Model C |
| | β | β | β | β | β | β |
| **Moderate self-report** | 0.22** | 0.06 | 0.02 | 0.18 | 0.04 | 0.00 |
| **Hard self-report** | 0.35*** | 0.32** | 0.23* | 0.30** | 0.29* | 0.07 |
| Perceived control | / | / | 0.40*** | / | / | 0.42*** |
| Self-rated health | / | / | / | / | / | 0.21* |
| Age | / | / | 0.23* | / | / | / |
| **Moderate ActiGraph** | 0.09 | 0.01 | -0.01 | 0.20 | 0.10 | 0.07 |
| **Vigorous ActiGraph** | 0.20 | 0.19 | 0.03 | 0.28** | 0.23* | 0.04 |
| Perceived control | / | / | 0.42*** | / | / | 0.42*** |
| Self-rated health | / | / | / | / | / | 0.23* |

*p<.05, **p<.01, ***p<.001

Model A: physical activity measures entered alone in separate models

Model B: model contains both physical activity measures

Model C: model contains both physical activity measures and all control variables found to be significant

β=standardized regression coefficient

When binary moderate and vigorous ActiGraph measures were included in the same model, they were both non-significantly related to depression, but the vigorous ActiGraph measure was significantly related to happiness (see Table 17). However, the significant relationship did not remain when control variables were included in the model.

Similar results were found when the activity measures were in tertiles (see Table 18). When moderate and hard self-report measures were included in the same model, both were non-significantly related to depression, but hard self-report was significantly related to happiness. The significant relationship did not remain when control variables were included in the model. When the moderate and vigorous ActiGraph measures were included in the same models, the vigorous measure was significantly related to both depression and happiness. However, the significant relationships did not remain when control variables were entered into the models.

Table 18. Results of multiple regression analyses including tertile physical activity measures of the same type (N=91)†

| | Depression | | | Happiness | | |
|---|---|---|---|---|---|---|
| | Model A | Model B | Model C | Model A | Model B | Model C |
| | β | β | β | β | β | β |
| **Moderate self-report 2nd tertile** | 0.11 | 0.07 | 0.04 | 0.06 | -0.02 | -0.05 |
| **Moderate self-report 3rd tertile** | 0.17 | 0.05 | 0.02 | 0.19 | 0.03 | -0.01 |
| **Hard self-report 2nd tertile** | 0.06 | 0.04 | -0.18 | 0.26* | 0.25* | 0.01 |
| **Hard self-report 3rd tertile** | 0.27* | 0.24 | 0.02 | 0.34** | 0.32* | 0.07 |
| Perceived control | / | / | 0.36** | / | / | 0.42*** |
| Self-rated health | / | / | 0.22* | / | / | 0.23* |
| **Moderate ActiGraph 2nd tertile** | 0.10 | -0.03 | 0.04 | 0.21 | 0.10 | 0.18 |
| **Moderate ActiGraph 3rd tertile** | 0.04 | -0.15 | -0.13 | 0.16 | -0.02 | 0.00 |
| **Vigorous ActiGraph 2nd tertile** | 0.26* | 0.30* | 0.15 | 0.17 | 0.16 | -0.03 |
| **Vigorous ActiGraph 3rd tertile** | 0.28* | 0.36* | 0.15 | 0.34** | 0.34* | 0.07 |
| Perceived control | / | / | 0.40*** | / | / | 0.45*** |
| Self-rated health | / | / | / | / | / | 0.23* |

*p<.05, **p<.01, ***p<.001

†first tertile is the reference group

Model A: physical activity measures entered alone in separate models

Model B: model contains both physical activity measures

Model C: model contains both physical activity measures and all control variables found to be significant

β=standardized regression coefficient

## DISCUSSION

Although the importance of physical activity for all age groups is recognized, few studies have examined physical activity in very elderly adults. This study is among the few to investigate systematically the relationship between different activity measures and well-being in the oldest-old, as well as the use of accelerometer with older adults, and the comparison of accelerometers and self-report measures with health outcomes.

**Compliance with wearing accelerometers**

Results indicated that very elderly individuals are compliant with wearing an accelerometer until the third day. Compliance was about 90% after the first day of wearing the accelerometer, above 80% for the second, and about 70% for the third. Therefore, compliance was acceptable up to two days. No gender effect was found. At 24 hours, women were 84% and men were near 100% compliant. Compliance was also not affected by age: both subgroups were at least 90% compliant at 24 hours.

The absence of differences between subgroups may have been the result of including healthy older adults. Although results indicated that health did not affect compliance, the lack of significant differences may have been due to greater homogeneity in this age group. Less healthy individuals would likely not still be living in the community and therefore not participate in this study. Because of this reduction in variability, it might be more difficult to detect differences between groups.

**Stability of ActiGraph counts**

ActiGraph readings were stable during the three-day period, including the subgroups of age and gender. All of the ActiGraph scores (mean, moderate, vigorous) were highly correlated and most of the t-tests conducted to compare scores across days were non-significant. Most intercepts and slopes were also non-significant. If both the intercept and the slope of an analysis do not differ from 0 and 1 respectively, it indicates that the scores from both days are similar to each other. That is, they would be found on a regression line with an intercept of 0 and a slope of 1, where an observation has identical values on both axes. However, the vigorous ActiGraph scores provided the highest number of significant slopes, indicating some instability between days. But all the correlations were high and all the t-tests were non-significant. Thus, although less so than the mean and moderate activity scores, the vigorous ActiGraph measure still demonstrated considerable stability.

Day-of-the-week analyses were also conducted and showed that ActiGraph scores did not vary between days of the week. Therefore, the days chosen for the oldest-old to wear an ActiGraph may have no effect on scores (e.g., no more activity during weekdays than weekends). These stable results may be due to the sample's relative inactivity. Very elderly individuals do not have the variable activity levels found in children (e.g., attending school on weekdays but not on weekends, and sport practices) or adults (e.g., having employment). Their activities tend to be more solitary and inside the home (Schroll, 2003; Strain et al., 2002), which would reduce activity variability and result in maintaining stable activity levels throughout the week.

Correlations between scores from individual days and an overall score with well-being were generally similar when comparing results from each day. Correlations between Day-1, -2, -3, and overall scores for ActiGraph readings and well-being were similar for mean ActiGraph counts and vigorous ActiGraph scores, but demonstrated more variability with moderate ActiGraph scores. Two of the latter scores (Day-1 and overall) were negatively correlated with depression. In addition, an anomalous finding was obtained when looking at all days combined, in that the moderate ActiGraph score was only weakly correlated with happiness (Pearson r=.13), much less strongly than was the case for the individual day scores where correlations ranged from .30 to .41. This may suggest that there was a problem with the definition of moderate scores. The relationship between mean activity counts and energy expenditure for some of the moderate-intensity activities in the Swartz et al. (2000) study may have greatly deviated from the regression line, much like some of the higher-intensity activities (e.g., power mowing). For example, 'playing with children' has a mean activity count greater than most activities included in the vigorous category.

**Comparing self-report measures of physical activity and ActiGraph counts**

Correlations were calculated to examine the relationship between activity measures. Correlations between ActiGraph scores were stronger than the correlations between the self-report measures, indicating that ActiGraph measures were more similar to each other than the self-report measures. Therefore, the moderate- and high-intensity self-report measures are capturing activity intensities more dissimilar to each other than the ActiGraph measures, that is, they are providing definitions of activity more unique from each other than are the ActiGraph measures. Therefore, they are more likely to be measuring different intensities. This suggests that the self-report intensities may be preferable to include as activity measures than the ActiGraph scores. The high-intensity measures were also more strongly correlated to each other than the lower-intensity measures to each other, indicating that the higher-intensity measures are more similar to each other than the lower-intensity measures. This may suggest that perceptions of activity levels are more accurate with high-intensity activities than with low-intensity activities.

Another method of examining the relationship between activity measures was the use of kappa statistic. It indicated that there was poor agreement between high-intensity measures of self-report and ActiGraph. Less than half of the participants were categorized in the same tertiles of high-intensity activity (low, moderate, high) in both measures. Therefore, there is a weak association between activity measures at the high-intensity levels. This suggests that perception of high-intensity activity levels in older adults do not correspond to vigorous levels of the objective measure of activity (i.e., accelerometer). Therefore, both measures are likely measuring different components of activity. The self-report measure may be measuring the perception of more global levels of activity, whereas the ActiGraph is limited to vigorous wrist movement.

**Comparing the predictive validity of physical activity measures**

Regression models were used to examine the relationship between activity measures and well-being. Regression models including high-intensity measures found that all were significantly related to well-being when entered alone. However, when both activity measures were included in the same model, they were both non-significantly related to depression and were both significantly related to happiness. These results are very similar to those obtained from ANOVA analyses. The differences may be due to the different statistical analyses: the ANOVA included activity variables with three levels, whereas the regression models included binary dummy variables.

The results indicated that high-intensity activity measures were more strongly related to happiness than depression. This may be due to the purpose of the depression scale: classifying respondents as depressed and not depressed. Because the sample for this study is composed of healthy community-dwelling older adults, few would be categorized as depressed. Therefore, the measure of depression may not be sensitive enough to detect differences in well-being in this sample.

Regression models including lower-intensity measures of physical activity found that self-report measures were slightly more often related to depression than happiness, whereas the ActiGraph measures were more often related to happiness than depression. The different relationships with well-being may be due to self-report and ActiGraph measures representing different aspects of physical activity. As mentioned in the previous section, the self-report measures may be measuring perception of more global aspects of activity, whereas the ActiGraph is limited to wrist movement. Self-report measures were also more likely to be related to well-being than ActiGraph measures when both measures were included in the same model. This may suggest that older adults' perception of lower-intensity activities is a stronger predictor of well-being than the ActiGraph, which is limited to wrist movement.

Moderate activities may be beneficial to health, but their effect may be mediated by high-intensity activities. When moderate- and high-intensity measures (self-report or ActiGraph) were included in the same models, the strength of the association between the high-intensity measure and well-being remained the same, whereas the strength of the association for the moderate-intensity greatly decreased. It may also be because high-intensity activities are more beneficial to health than moderate-intensity activities. It should be noted here that no multicollinearity was found in the models. Therefore, the activity measures were providing unique contributions. Another explanation is that the sample was not large enough to detect significant differences for the moderate-intensity measures.

Physical activity was often no longer found significantly related to well-being when including control variables. This suggests that physical activity may be mediated by these variables. Perceived control was associated with well-being in all regression models and rendered the associations between physical activity and well-being non-significant. Although the hard self-report measure remained significant in some analyses when controlling for perceived control, the standardized slopes were reduced. Perceived control has been identified as a mediator associated with physical activity, but studies investigating the variables mediating physical activity have usually looked at physical activity as an outcome variable rather than a predictor. For example, perceived control has been found to mediate the relationship between ethnicity and physical activity (Rhodes, Macdonald, & McKay, 2006), and autonomous motives to perform physical activity and physical activity intentions (Hagger, Chatzisarantis, & Biddle, 2002). It has also been found to predict independently change in vigorous physical activity (Motl et al., 2005).

The ActiGraph measures were inconsistently related to well-being, except at the very intense levels. As mentioned in a previous section, there may be a problem with the definition of the moderate-intensity ActiGraph measure. It may also be that moderate-intensity activities (e.g., daily activities) are not related to well-being. A person may be involved in these activities because they have to, rather than want to perform them. The voluntary nature of the high-intensity activities (e.g., gardening, sport) may be influencing the relationship between these activities and well-being. That is, people performing more activities voluntarily may be enjoying these activities more than a person who feels obligated to perform.

It may also be due to the positioning of the ActiGraph. Wearing it on the hip is more strongly related to energy expenditure than on the wrist (Brooks et al., 2004; Swartz et al., 2000). ActiGraphs worn on the wrist may only be appropriate for individuals who have limited mobility (e.g., frequent use of wheelchair) and therefore little waist movement. Another reason for the weaker relationships would be the definition of activity provided for ActiGraph measures. The initial equation to convert activity counts into energy expenditure included high-intensity activities with low wrist movement (e.g., mowing, pulling/carrying golf clubs; Swartz et al., 2000). These activities affected the regression equation by producing a high intercept (3 METs). Based on that equation, all activity counts of 0 and above would be incorrectly considered high-intensity activity and every participant would have a hard activity score of 100% (i.e., proportion of time spent at 3 METs and above).

Another issue with the equation that converted activity counts into energy expenditure is that it included uncommon activities for older adults. These equations should only include activities that are common to this age group rather than include uncommon activities (e.g., mowing, tennis). Although some individuals in this age group still participate in these activities, the majority do not. Other activities such as reading, watching television, and listening to the radio should be included as well. These activities are common in older adults and they would produce low activity counts. In turn, the inclusion of these activities would lower the intercept and possibly provide an acceptable regression equation.

The list of activities used in this thesis were common activities that the oldest-old participate, therefore, other activities likely do not need to be added. The activity of sport would need to be more specific to identify particular activities, such as walking. Until a compendium of activities with MET values for older adults has been produced, it appears to be acceptable to use physical involvement as a substitute. In addition, it may be preferable to use physical involvement because it is more flexible than MET values, in that it can control for intensity differences between individuals (i.e., healthier individuals having a higher score than less healthy individuals for the same activity).

In summary, the oldest-old's compliance for wearing the ActiGraph is high for two days. ActiGraph scores are stable over a three-day period, which might indicate that one day of ActiGraph information is acceptable. The self-report and ActiGraph measures correlated poorly with each other, indicating low congruence between both measures. Both self-report and ActiGraph measures were inconsistently related to well-being, except for the high-intensity measures.

**Limitations**

There are limitations to the results of this thesis. The small sample size may have limited the ability to report significant differences. The relationship between activity and well-being cannot be generalized to other health outcomes. Different results may be produced with more objective health measures. It is likely that activity would be more strongly related to more objective measures, as found in previous research (e.g., mortality; Blair et al., 2000). The results of the ActiGraph cannot be generalized to individuals wearing it on the hip. Compliance of participants and stability of scores may differ if worn on the hip. When worn on the wrist, the ActiGraph is similar to wearing a watch, which is commonly worn by people. Most individuals do not wear an instrument around their waist, which may affect compliance. Activity counts between hip and wrist placement are not similar (Swartz et al., 2000), and it is unknown if stable wrist movement translates to stable hip movement in older adults.

Although the hard self-report measure was related to well-being in some analyses, the measure can be improved. Rather than asking respondents to identify the frequency of activity and then the typical duration per activity, respondents could indicate the average duration of each activity during a typical week, such as in the CHAMPS questionnaire (Stewart et al., 2001). This would reduce the error estimation by eliminating the need to multiply items.

## IMPLICATIONS

The oldest-old are the fastest growing segment of the population (Statistics Canada, 2001). Their proportion is expected to rise from 24% of the population aged 65 and older in 2000 to 36% in 2051. Finding means of maintaining their health will become more important in the future as health expenditures increase with an aging population. Future health expenditure increases due uniquely to aging has been estimated to be about 0.8 percent per year from 2000 to 2030 (Pollock, 2001). Physical activity can not only maintain or improve older adults' health, but also control health care costs (Munro, Brazier, Davey, & Nicholl, 1997).

This study has helped to indicate that one day is sufficient to provide usual activity levels in the oldest-old, when the ActiGraph is worn on the wrist. This can decrease the cost of future studies including participants of this age group who wear an ActiGraph on the wrist (e.g., number of ActiGraphs needed, cost of batteries, and cost of data cleaning). This study has also helped to illustrate the variability in the relationship between activity measures and well-being. The choice of activity measure is important due to the variability of results between measures.

# REFERENCES

Abler, R. M. & Fretz, B. R. (1988). Self-efficacy and competence in independent living among oldest old persons. *Journal of Gerontology, 43,* S138-S143.

Ainsworth, B. E. (2002). The compendium of physical activities tracking guide. Retrieved [May 15, 2005] from the World Wide Web. Columbia, South Carolina, University of South Carolina.

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J. et al. (2000). Compendium of physical activities: an update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise, 32,* S498-S504.

Alexander, N. B., Guire, K. E., Thelen, D. G., Ashton-Miller, J. A., Schultz, A. B., Grunawalt, J. C. et al. (2000). Self-reported walking ability predicts functional mobility performance in frail older adults. *Journal of the American Geriatrics Society, 48,* 1408-1413.

Arent, S. M., Landers, D. M., & Etnier, J. L. (2000). Effects of exercise on mood in older adults: a meta-analytic review. *Journal of Aging and Physical Activity, 8,* 407-430.

Backman, L., Small, B. J., Forsell, Y., Winblad, B., & Berger, A. K. (1999). Dr. Backman and colleagues reply [Letter to the Editor]. *American Journal of Psychiatry, 156,* 1291-1292.

Baltes, P. B. & Smith, J. (2002). New frontiers in the future of aging: From successful aging of the young old to the dilemmas of the Fourth Age. Keynote paper presented to the Valencia Forum .

Baltes, P. B. & Baltes, M. M. (1990). Psychological perspectives on successful aging: the model of selective optimization with compensation. In P.B.Baltes & M. M. Baltes

(Eds.), *Successful aging: perspectives from the behavioral sciences* (pp. 1-34). Cambridge, England and New York, NY.

Bierman, A. S., Bubolz, T. A., Fisher, E. S., & Wasson, J. H. (1999). How well does a single question about health predict the financial health of Medicare managed care plans? *Effective Clinical Practice, 2,* 56-62.

Bijnen, F. C., Feskens, E. J., Caspersen, C. J., Nagelkerke, N., Mosterd, W. L., & Kromhout, D. (1999). Baseline and previous physical activity in relation to mortality in elderly men: the Zutphen Elderly Study. *American Journal of Epidemiology, 150,* 1289-1296.

Blair, S. N. & Wei, M. (2000). Sedentary habits, health, and function in older women and men. *American Journal of Health Promotion, 15,* 1-8.

Bootsma-van-der-Wiel-Annetje, Gussekloo, J., Craen-Anton, J. M., van Exel, E., Bloem, B. R., & Westendorp-Rudi, G. J. (2002). Common chronic diseases and general impairments as determinants of walking disability in the oldest-old population. *Journal of the American Geriatrics Society, 50,* 1405-1410.

Brage, S., Wedderkopp, N., Andersen, L. B., & Froberg, K. (2003a). Influence of step frequency on movement intensity predictions with the CSA accelerometer: A field validation study in children. *Pediatric Exercise Science, 15,* 277-287.

Brage, S., Wedderkopp, N., Franks, P. W., Andersen, L. B., & Froberg, K. (2003b). Reexamination of validity and reliability of the CSA monitor in walker and running. *Medicine and Science in Sports and Exercise, 35,* 1447-1454.

Branch, L. G. & Jette, A. M. (1982). A prospective study of long-term care institutionalization among the aged. *American Journal of Public Health, 72,* 1372-1379.

Brockman, H. (2002). Why is less money spent on health care for the elderly than for the rest of the population? Health care rationing in German hospitals. *Social Science and Medicine, 55,* 593-608.

Broe, G. A., Creasey, H., Jorm, A. F., Bennett, H. P., Casey, B., Waite, L. M. et al. (1998). Health habits and risk of cognitive impairment and dementia in old age: a prospective study on the effects of exercise, smoking and alcohol consumption. *Australian and New Zealand Journal of Public Health, 22,* 621-623.

Brooks, A. G., Withers, R. T., Gore, C. J., Vogler, A. J., Plummer, J., & Cormack, J. (2004). Measurement and prediction of METs during household activities in 35- to 45-year-old females. *European Journal of Applied Physiology, 91,* 638-648.

Buchner, D. M. (1997). Preserving mobility in older adults. *Western Journal of Medicine, 167,* 258-264.

Burton, L. C., Shapiro, S., & German, P. S. (1999). Determinants of physical activity initiation and maintenance among community-dwelling older persons. *Preventive Medicine, 29,* 422-430.

Cartmel, B. & Moon, T. E. (1992). Comparison of 2 Physical-Activity Questionnaires, with A Diary, for Assessing Physical-Activity in An Elderly Population. *Journal of Clinical Epidemiology, 45,* 877-883.

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,* 126-131.

Chappell, N. L. (1983). Informal support networks among the elderly. *Research on Aging, 5,* 77-99.

Chipperfield, J. G., Perry, R. P., Volk, J. S., & Hladkyj, S. (2003). The Successful Aging Study: Perceived control in later life. Technical Report #HLHPRI103, Health, Leisure, and Human Performance Research Institute, University of Manitoba, Winnipeg, Manitoba.

Chipperfield, J. G., Campbell, D. W., & Perry, R. P. (2004). Stability in perceived control; Implications for well-being among older individuals. *Journal of Aging and Health*, *16*, 116-147.

Computer Science and Application. Inc. (1995). Activity monitor operator's manual. Model 7164. Shalimar, FL.

Connelly, D. M. (2000). Resisted exercise training of institutionalized older adults for improved strength and functional mobility: a review. *Topics in Geriatric Rehabilitation, 15,* 6-28.

Cooper-Patrick, L., Ford, D. E., Mead, L. A., Chang, P. P., & Klag, M. J. (1997). Exercise and depression in midlife: a prospective study. *American Journal of Public Health, 87,* 670-673.

Costa, P. T. & McCrae, R. R. (1995). Domains and facets: Hierarchical personality assessment using the Revised NEO Personality Inventory. *Journal of Personality Assessment, 64,* 21-50.

Craig, C. L., Russell, S. J., Cameron, C., & Bauman, A. (2004). Twenty-year trends in physical activity among Canadian adults. *Canadian Journal of Public Health.Revue Canadienne de Sante Publique, 95,* 59-63.

Crespo, C. J., Palmieri, M. R., Perdomo, R. P., Mcgee, D. L., Smit, E., Sempos, C. T. et al. (2002). The relationship of physical activity and body weight with all-cause mortality: results from the Puerto Rico Heart Health Program. *Annals of Epidemiology, 12,* 543-552.

Crombie, I. K., Irvine, L., Williams, B., McGinnis, A. R., Slane, P. W., Alder, E. M. et al. (2004). Why older people do not participate in leisure time physical activity: a survey of activity levels, beliefs and deterrents. *Age and Ageing, 33,* 287-292.

Crystal, S., Sambamoorthi, U., Walkup, J. T., & Akinicigil, A. (2003). Diagnosis and treatment of depression in the elderly Medicare population: predictors, disparities, and trends. *Journal of the American Geriatrics Society, 51,* 1718-1728.

Cumming, E. & Henry, W. E. (1961). *Growing old: the process of disengagement.* New York, NY: Basic Books.

d'Epinay, C. J. L. & Bickel, J. F. (2003). Do "Young-Old" Exercisers Feel Better Than Sedentary Persons? A Cohort Study in Switzerland. *Canadian Journal on Aging, 22,* 155-165.

Dallosso, H. M., Morgan, K., Bassey, E. J., Ebrahim, S. B., Fentem, P. H., & Arie, T. H. (1988). Levels of customary physical activity among the old and the very old living at home. *Journal of Epidemiology and Community Health, 42,* 121-127.

Damush, T. M. & Damush, J. G., Jr. (1999). The effects of strength training on strength and health-related quality of life in older adult women. *Gerontologist, 39,* 705-710.

Davies, S. W., Jordan, S. L., & Lipkin, D. P. (1992). Use of limb movement sensors as indicators of the level of everyday physical activity in chronic congestive heart failure. *American Journal of Cardiology, 69,* 1581-1586.

Denton, F. T. & Spencer, B. G. (2002). Some demographic consequences of revising the definition of "old age" to reflect future changes in life table probabilities. *Canadian Journal on Aging, 21,* 349-356.

DiPietro, L. (2001). Physical activity in aging: changes in patterns and their relationship to health and function. *Journals of Gerontology.Series A, Biological Sciences and Medical Sciences, 56 Spec No 2,* 13-22.

DiPietro, L., Caspersen, C. J., Ostfeld, A. M., & Nadel, E. R. (1993). A survey for assessing physical activity among older adults. *Medicine and Science in Sports and Exercise, 25,* 628-642.

Droomers, M., Schrijvers, C. T., & Mackenbach, J. P. (2001). Educational level and decreases in leisure time physical activity: predictors from the longitudinal GLOBE study. *Journal of Epidemiology and Community Health, 55,* 562-568.

Dubbert, P. M., Vander Weg, M. W., Kirchner, K. A., & Shaw, B. (2004). Evaluation of the 7-day physical activity recall in urban and rural men. *Medicine and Science in Sports and Exercise, 36,* 1646-1654.

Ellekjaer, H., Holmen, J., Ellekjaer, E., & Vatten, L. (2000). Physical activity and stroke mortality in women. Ten-year follow-up of the Nord-Trondelag health survey, 1984-1986. *Stroke, 31,* 14-18.

Emery, C. F., Schein, R. L., Hauck, E. R., & MacIntyre, N. R. (1998). Psychological and cognitive outcomes of a randomized trial of exercise among patients with chronic obstructive pulmonary disease. *Health Psychology, 17,* 232-240.

Eysenck, H. J., Barrett, P., Wilson, G., & Jackson, C. (1992). Primary trait measurement of the 21 components of the P-E-N system. *European Journal of Psychological Assessment, 8,* 109-117.

Ferrucci, L., Izmirlian, G., Leveille, S., Phillips, C. L., Corti, M. C., Brock, D. B. et al. (1999). Smoking, physical activity, and active life expectancy. *American Journal of Epidemiology, 149,* 645-653.

Feskanich, D., Willett, W., & Colditz, G. (2002). Walking and leisure-time activity and risk of hip fracture in postmenopausal women. *JAMA, 288,* 2300-2306.

Focht, B. C., Sanders, W. M., Brubaker, P. H., & Rejeski, W. (2003). Initial validation of the CSA activity monitor during rehabilitative exercise among older adults with chronic disease. *Journal of Aging and Physical Activity, 11,* 293-304.

Fontane, P. E. (1996). Exercise, fitness, and feeling well. *American Behavioral Scientist, 39,* 288-305.

Fozard, J. L. (1999). Epidemiologists try many ways to show that physical activity is good for seniors' health and longevity. Review of special issue of Journal of Aging and Physical Activity: The Evergreen Project. *Experimental Aging Research, 25,* 175-182.

Freedson, P. S., Melanson, E., & Sirard, J. (1998). Calibration of the Computer Science and Applications, Inc. accelerometer. *Medicine and Science in Sports and Exercise, 30,* 777-781.

Gardner, A. W. & Poehlman, E. T. (1998). Assessment of free-living daily physical activity in older claudicants: Validation against the doubly labeled water technique. *Journals of Gerontology Series A-Biological Sciences and Medical Sciences, 53,* M275-M280.

Gilbart, E. E. & Hirdes, J. P. (2000). Stress, social engagement and psychological well-being in institutional settings: evidence based on the Minimum Data Set 2.0. *Canadian Journal on Aging, 19,* 50-66.

Hagger, M. S., Chatzisarantis, N. L., & Biddle, S. J. (2002). The influence of autonomous and controlling motives on physical activity intentions within the Theory of Planned Behaviour. *British Journal of Health Psychology, 7,* 283-297.

Hamarat, E., Thompson, D., Aysan, F., Steele, D., Matheny, K., & Simons, C. (2002). Age differences in coping resources and satisfaction with life among middle-aged, young-old, and oldest-old adults. *Journal of Genetic Psychology, 163,* 360-367.

Harada, N. D., Chiu, V., King, A. C., & Stewart, A. L. (2001). An evaluation of three self-report physical activity instruments for older adults. *Medicine and Science in Sports and Exercise, 33,* 962-970.

Havighurst, R. J. & Albrecht, R. (1953). *Older people*. New York: Longmans Green.

Hirvensalo, M., Rantanen, T., & Heikkinen, E. (2000). Mobility difficulties and physical activity as predictors of mortality and loss of independence in the community-living older population. *Journal of the American Geriatrics Society, 48,* 493-498.

Hong, T. B., Zarit, S. H., & Johansson, B. (2003). Mild cognitive impairment in the oldest old: a comparison of two approaches. *Aging and Mental Health, 7,* 271-276.

Horgas, A. L., Wilms, H. U., & Baltes, M. M. (1998). Daily life in very old age: everyday activities as expression of successful living. *Gerontologist, 38,* 556-568.

Janz, K. F. (1994). Validation of the CSA accelerometer for assessing children's physical activity. *Medicine and Science in Sports and Exercise, 26,* 369-375.

Janz, K. F., Witt, J., & Mahoney, L. T. (1995). The stability of children's physical activity as measured by accelerometry and self-report. *Medicine and Science in Sports and Exercise, 27,* 1326-1332.

Johansson, S. E. & Sundquist, J. (1999). Change in lifestyle factors and their influence on health status and all-cause mortality. *International Journal of Epidemiology, 28,* 1073-1080.

Kalapotharakos, V. I., Michalopoulou, M., Godolias, G., Tokmakidis, S. P., Malliou, P. V., & Gourgoulis, V. (2004). The effects of high- and moderate-resistance training on muscle function in the elderly. *Journal of Aging and Physical Activity, 12,* 131-143.

Kaplan, M. S., Newsom, J. T., McFarland, B. H., & Lu, L. (2001). Demographic and psychosocial correlates of physical activity in late life. *American Journal of Preventive Medicine, 21,* 306-312.

Katz, S., Ford, A. B., Moskowitz, R. W., Jackson, B. S., & Jaffe, M. W. (1963). Studies of illness in the aged. The index of ADL: A standardized measure of biological and psychosocial function. *Journal of the American Medical Association, 185*, 914-919.

Keller, C. & Fleury, J. (2000). *Health promotion for the elderly*. Thousand Oaks, CA: Sage Publications.

Keysor, J. J. & Jette, A. M. (2001). Have we oversold the benefit of late-life exercise? *Journals of Gerontology.Series A, Biological Sciences and Medical Sciences, 56,* M412-M423.

Kimberlin, C. L., Pendergast, J. F., Berardo, D. H., & McKenzie, L. C. (1998). Issues related to using a short-form of the Center for Epidemiological Studies-Depression Scale. *Psychological Reports, 83,* 411-421.

Knight, T. & Ricciardelli, L. A. (2003). Successful aging: perceptions of adults aged between 70 and 101 years. *International Journal of Aging and Human Development, 56,* 223-245.

Kochersberger, G., McConnell, E., Kuchibhatla, M. N., & Pieper, C. (1996). The reliability, validity, and stability of a measure of physical activity in the elderly. *Archives of Physical Medicine and Rehabilitation, 77,* 793-795.

Latham, N. K., Bennett, D. A., Stretton, C. M., & Anderson, C. S. (2004). Systematic review of progressive resistance strength training in older adults. *Journals of Gerontology.Series A, Biological Sciences and Medical Sciences, 59,* 48-61.

Laurin, D., Verreault, R., Lindsay, J., MacPherson, K., & Rockwood, K. (2001). Physical activity and risk of cognitive impairment and dementia in elderly persons. *Archives of Neurology, 58,* 498-504.

Lee, C. & Russell, A. (2003). Effects of physical activity on emotional well-being among older Australian women: cross-sectional and longitudinal analyses. *Journal of Psychosomatic Research, 54,* 155-160.

Leidy, N. K., Abbott, R. D., & Fedenko, K. M. (1997). Sensitivity and reproducibility of the dual-mode actigraph under controlled levels of activity intensity. *Nursing Research, 46,* 5-11.

Lemon, B. W., Bengtson, V. L., & Peterson, J. A. (1972). Exploration of the activity theory of aging: activity types and life satisfaction among in-movers to a retirement community. *Journal of Gerontology, 27,* 511-523.

Lindenberger, U. & Baltes, P. B. (1997). Intellectual functioning in old and very old age: cross-sectional results from the Berlin Aging Study. *Psychology and Aging, 12,* 410-432.

Lord, S. R. & Menz, H. B. (2002). Physiologic, psychologic, and health predictors of 6-minute walk performance in older people. *Archives of Physical Medicine and Rehabilitation, 83,* 907-911.

Lowther, M., Mutrie, N., Loughlan, C., & McFarlane, C. (1999). Development of a Scottish physical activity questionnaire: a tool for use in physical activity interventions. *British Journal of Sports Medicine, 33,* 244-249.

MacRae, P. G., Asplund, L. A., Schnelle, J. F., Ouslander, J. G., Abrahamse, A., & Morris, C. (1996). A walking program for nursing home residents: effects on walk endurance, physical activity, mobility, and quality of life. *Journal of the American Geriatrics Society, 44,* 175-180.

Manton, K. G. (1986). Cause specific mortality patterns among the oldest old: multiple cause of death trends 1968 to 1980. *Journal of Gerontology, 41,* 282-289.

Matthews, C. E., Ainsworth, B. E., Thompson, R. W., & Bassett, D. R., Jr. (2002). Sources of variance in daily physical activity levels as measured by an accelerometer. *Medicine and Science in Sports and Exercise, 34,* 1376-1381.

Maurer, M. S., Luchsinger, J. A., Wellner, R., Kukuy, E., & Edwards, N. M. (2002). Effect of body mass index on complications from cardiac surgery in the oldest old. *Journal of the American Geriatrics Society, 50,* 988-994.

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,* 608-617.

McCrae, R. R. & Costa, P. T. (1995). Trait explanations in personality psychology. *European Journal of Personality, 9,* 231-252.

McCrae, R. R., Costa, P. T. J., Ostendorf, F., Angleitner, A., Hrebickova, M., Avia, M. D. et al. (2000). Nature over nurture: Temperament, personality, and life span development. *Journal of Personality and Social Psychology, 78,* 173-186.

McGinnis, J. M. & Foege, W. H. (1993). Actual causes of death in the United States. *JAMA, 270,* 2207-2212.

Meijer, G. A., Westerterp, K. R., Koper, H., & ten Hoor, F. (1989). Assessment of energy expenditure by recording heart rate and body acceleration. *Medicine and Science in Sports and Exercise, 21,* 343-347.

Menec, V. H. & Chipperfield, J. G. (1997). Remaining active in later life: The role of locus of control in seniors' leisure activity participation, health, and life satisfaction. *Journal of Aging and Health*, *9*, 105-125.

Mensink, G. B., Ziese, T., & Kok, F. J. (1999). Benefits of leisure-time physical activity on the cardiovascular risk profile at older age. *International Journal of Epidemiology, 28,* 659-666.

Metcalf, B. S., Curnow, J. S. H., Evans, C., Voss, L. D., & Wilkin, T. J. (2002). Technical reliability of the CSA activity monitor: The EarlyBird Study. *Medicine and Science in Sports and Exercise, 34,* 1533-1537.

Michel, B. A., Lane, N. E., Bjorkengren, A., Bloch, D. A., & Fries, J. F. (1992). Impact of running on lumbar bone density: a 5-year longitudinal study. *Journal of Rheumatology, 19,* 1759-1763.

Mokdad, A. H., Marks, J. S., Stroup, D. F., & Gerberding, J. L. (2004). Actual causes of death in the United States, 2000. *JAMA, 291,* 1238-1245.

Motl, R. W., Dishman, R. K., Ward, D. S., Saunders, R. P., Dowda, M., Felton, G. et al. (2005). Comparison of barriers self-efficacy and perceived behavioral control for explaining physical activity across 1 year among adolescent girls. *Health Psychology, 24,* 106-111.

Munro, J., Brazier, J., Davey, R., & Nicholl, J. (1997). Physical activity for the over-65s: could it be a cost-effective exercise for the NHS? *Journal of Public Health Medicine, 19,* 397-402.

Neugarten, B. L. (1975). The future and the young-old. *Gerontologist, 15,* 4-9.

Neugarten, B. L., Havighurst, R. J., & Tobin, S. S. (1968). Personality and patterns of aging. In B.L.Neugarten (Ed.), *Middle age and aging* (pp. 77-102). Chicago: University of Chicago Press.

Ostbye, T., Taylor, D. H., & Jung, S. H. (2002). A longitudinal study of the effects of tobacco smoking and other modifiable risk factors on ill health in middle-aged and old Americans: results from the Health and Retirement Study and Asset and Health Dynamics among the Oldest Old survey. *Preventive Medicine, 34,* 334-345.

Paffenbarger, R. S., Jr., Wing, A. L., & Hyde, R. T. (1978). Physical activity as an index of heart attack risk in college alumni. *American Journal of Epidemiology, 108,* 161-175.

Pate, R. R., Pratt, M., Blair, S. N., Haskell, W. L., Macera, C. A., Bouchard, C. et al. (1995). Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA, 273,* 402-407.

Patterson, S. M., Krantz, D. S., Montgomery, L. C., Deuster, P. A., Hedges, S. M., & Nebel, L. E. (1993). Automated physical activity monitoring: validation and comparison with physiological and self-report measures. *Psychophysiology, 30,* 296-305.

Pollock, A. (2001). Aging as a health care cost driver. *Health Policy Research Bulletin, 1,* 10-12.

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

Rhodes, R. E., Macdonald, H. M., & McKay, H. A. (2006). Predicting physical activity intention and behaviour among children in a longitudinal sample. *Social Science and Medicine, 62,* 3146-3156.

Rhodes, R. E., Courneya, K. S., & Jones, L. W. (2002). Personality, the theory of planned behavior and exercise: A unique role for extroversion's activity facet. *Journal of Applied Social Psychology, 32,* 1721-1736.

Rhodes, R. E., Courneya, K. S., & Jones, L. W. (2004). Personality and social cognitive influences on exercise behavior: Adding the activity trait to the theory of planned behavior. *Psychology of Sport and Exercise, 5,* 243-254.

Riche, M. F. (1985). Oldest old. *American Demographics, 7,* 44-45.

Rikli, R. E. (2000). Reliability, validity, and methodological issues in assessing physical activity in older adults. *Research Quarterly for Exercise and Sport, 71,* S89-S96.

Robertson, D., Rockwood, K., & Stolee, P. (1982). A short mental status questionnaire. *Canadian Journal on Aging, 1,* 16-20.

Rockhill, B., Willett, W. C., Manson, J. E., Leitzmann, M. F., Stampfer, M. J., Hunter, D. J. et al. (2001). Physical activity and mortality: a prospective study among women. *American Journal of Public Health, 91,* 578-583.

Rosenberg, M., Bull, F. C., Braham, R., Cowper, K., & Booth, M. (2002). Assessing the accumulation of moderate-intensity physical activity in adults. *Medicine and Science in Sports and Exercise, 34,* S207.

Rosenwaike, I. & Dolinsky, A. (1987). Changing demographic determinants of the growth of the extreme aged. *Gerontologist, 27,* 275-280.

Rowe, J. W. & Kahn, R. L. (1997). Successful aging. *Gerontologist, 37,* 433-440.

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

Sallis, J. F., Haskell, W. L., Wood, P. D., Fortmann, S. P., Rogers, T., Blair, S. N. et al. (1985). Physical activity assessment methodology in the Five-City Project. *American Journal of Epidemiology, 121,* 91-106.

Sallis, J. F., Strikmiller, P. K., Harsha, D. W., Feldman, H. A., Ehlinger, S., Stone, E. J. et al. (1996). Validation of interviewer- and self-administered physical activity checklists for fifth grade students. *Medicine and Science in Sports and Exercise, 28,* 840-851.

Satariano, W. A., Haight, T. J., & Tager, I. B. (2000). Reasons given by older people for limitation or avoidance of leisure time physical activity. *Journal of the American Geriatrics Society, 48,* 505-512.

Schoenfelder, D. P. & Rubenstein, L. M. (2004). An exercise program to improve fall-related outcomes in elderly nursing home residents. *Applied Nursing Research, 17,* 21-31.

Schroll, M. (2003). Physical activity in an ageing population. *Scandinavian Journal of Medicine and Science in Sports, 13,* 63-69.

Schuit, A. J., Feskens, E. J., Launer, L. J., & Kromhout, D. (2001). Physical activity and cognitive decline, the role of the apolipoprotein e4 allele. *Medicine and Science in Sports and Exercise, 33,* 772-777.

Schulz, R., Mittelmark, M., Kronmal, R., Polak, J. F., Hirsch, C. H., German, P. et al. (1994). Predictors of perceived health status in elderly men and women. The Cardiovascular Health Study. *Journal of Aging and Health, 6,* 419-447.

Sesso, H. D., Paffenbarger, R. S., Jr., & Lee, I. M. (2000). Physical activity and coronary heart disease in men: The Harvard Alumni Health Study. *Circulation, 102,* 975-980.

Seynnes, O., Fiatarone Singh, M. A., Hue, O., Pras, P., Legros, P., & Bernard, P. L. (2004). Physiological and functional responses to low-moderate versus high-intensity progressive resistance training in frail elders. *Journals of Gerontology.Series A, Biological Sciences and Medical Sciences, 59,* 503-509.

Shephard, R. J. (1997). *Aging, physical activity, and health.* Champaign, IL: Human Kinetics.

Speakman, J. R. (1998). The history and theory of the doubly labeled water technique. *American Journal of Clinical Nutrition, 68,* 932S-938S.

Spirduso, W. W. & Cronin, D. L. (2001). Exercise dose-response effects on quality of life and independent living in older adults. *Medicine and Science in Sports and Exercise, 33,* S598-S608.

Starling, R. D., Matthews, D. E., Ades, P. A., & Poehlman, E. T. (1999). Assessment of physical activity in older individuals: a doubly labeled water study. *Journal of Applied Physiology, 86,* 2090-2096.

Stathi, A., Fox, K. R., & McKenna, J. (2002). Physical activity and dimensions of subjective well-being in older adults. *Journal of Aging and Physical Activity, 10,* 76-92.

Statistics Canada. (2001). Population projections for Canada, provinces and territories, 2000-2026. [91-520-XPB]. Ottawa, Ministry of Industry.

Stessman, J., Maaravi, Y., Hammerman-Rozenberg, R., & Cohen, A. (2000). The effects of physical activity on mortality in the Jerusalem 70-Year-Olds Longitudinal Study. *Journal of the American Geriatrics Society, 48,* 499-504.

Stewart, A. L., Mills, K. M., King, A. C., Haskell, W. L., Gillis, D., & Ritter, P. L. (2001). CHAMPS physical activity questionnaire for older adults: outcomes for interventions. *Medicine and Science in Sports and Exercise, 33,* 1126-1141.

Stones, M. J. & Kozma, A. (1986). "Happy are they who are happy . . ." a test between two causal models of relationships between happiness and its correlates. *Experimental Aging Research, 12,* 23-29.

Strain, L. A., Grabusic, C. C., Searle, M. S., & Dunn, N. J. (2002). Continuing and ceasing leisure activities in later life: a longitudinal study. *Gerontologist, 42,* 217-223.

Strawbridge, W. J., Wallhagen, M. I., & Cohen, R. D. (2002). Successful aging and well-being: self-rated compared with Rowe and Kahn. *Gerontologist, 42,* 727-733.

Sugimoto, A., Hara, Y., Findley, T. W., & Yonemoto, K. (1997). A useful method for measuring daily physical activity by a three-direction monitor. *Scandinavian Journal of Rehabilitation Medicine, 29,* 37-42.

Swartz, A. M., Strath, S. J., Bassett, D. R., Jr., O'Brien, W. L., King, G. A., & Ainsworth, B. E. (2000). Estimation of energy expenditure using CSA accelerometers at hip and wrist sites. *Medicine and Science in Sports and Exercise, 32,* S450-S456.

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,* 128-141.

Tanaka, H., Taira, K., Arakawa, M., Urasaki, C., Yamamoto, Y., Okuma, H. et al. (2002). Short naps and exercise improve sleep quality and mental health in the elderly. *Psychiatry and Clinical Neurosciences, 56,* 233-234.

Tate, R. B., Lah, L., & Cuddy, T. E. (2003). Definition of successful aging by elderly Canadian males: the Manitoba Follow-Up Study. *The Gerontologist, 43,* 735-744.

Taylor, H. L., Jacobs, D. R., Jr., Schucker, B., Knudsen, J., Leon, A. S., & Debacker, G. (1978). A questionnaire for the assessment of leisure time physical activities. *Journal of Chronic Diseases, 31,* 741-755.

Taylor, L., Whittington, F., Hollingsworth, C., Ball, M., King, S., Patterson, V. et al. (2003). Assessing the effectiveness of a walking program on physical function of residents living in an assisted living facility. *Journal of Community Health Nursing, 20,* 15-26.

Trost, S. G., Pate, R. R., Freedson, P. S., Sallis, J. F., & Taylor, W. C. (2000). Using objective physical activity measures with youth: how many days of monitoring are needed? *Medicine and Science in Sports and Exercise, 32,* 426-431.

Tudor-Locke, C. E. & Myers, A. M. (2001). Challenges and opportunities for measuring physical activity in sedentary adults. *Sports Medicine, 31,* 91-100.

U.S.Department of Health and Human Services (1996). *Physical Activity and Health: A Report of the Surgeon General* (Rep. No. 242). Atlanta: U.S. Department of Health and Human Services.

Walsh, J. M., Pressman, A. R., Cauley, J. A., & Browner, W. S. (2001). Predictors of physical activity in community-dwelling elderly white women. *Journal of General Internal Medicine, 16,* 721-727.

Wannamethee, S. G., Shaper, A. G., & Walker, M. (2000). Physical activity and mortality in older men with diagnosed coronary heart disease. *Circulation, 102,* 1358-1363.

Washburn, R. A. (2000). Assessment of physical activity in older adults. *Research Quarterly for Exercise and Sport, 71,* S79-S88.

Washburn, R. A. & Copay, A. G. (1999). Assessing physical activity during wheelchair pushing: Validity of a portable accelerometer. *Adapted Physical Activity Quarterly, 16,* 290-299.

Washburn, R. A. & Ficker, J. L. (1999). Physical Activity Scale for the Elderly (PASE): the relationship with activity measured by a portable accelerometer. *Journal of Sports Medicine and Physical Fitness, 39,* 336-340.

Washburn, R. A., Jette, A. M., & Janney, C. A. (1990). Using age-neutral physical activity questionnaires in research with the elderly. *Journal of Aging and Health, 2,* 341-356.

Wilcox, S., Tudor-Locke, C. E., & Ainsworth, B. E. (2002). Physical activity patterns, assessment, and motivation in older adults. In R.J.Shephard (Ed.), *Gender, physical activity, and aging* (pp. 13-39). Boca Raton, FL: CRC Press.

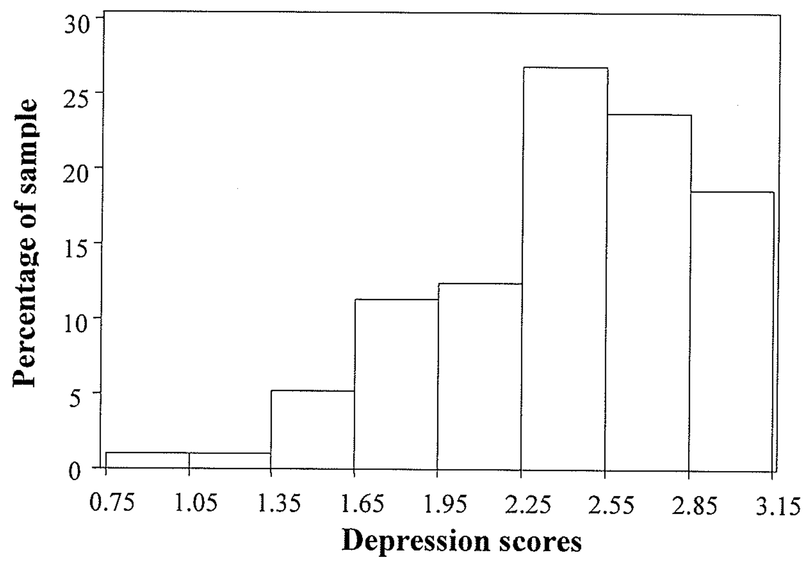
Young, D. R., Jee, S. H., & Appel, L. J. (2001). A comparison of the Yale Physical Activity Survey with other physical activity measures. *Medicine and Science in Sports and Exercise, 33,* 955-961.

Yu, S., Yarnell, J. W., Sweetnam, P. M., & Murray, L. (2003). What level of physical activity protects against premature cardiovascular death? The Caerphilly study. *Heart, 89,* 502-506.

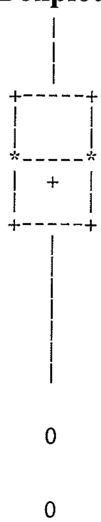
Zimmer, Z., Chayovan, N., Lin, H. S., & Natividad, J. (2004). How indicators of socioeconomic status relate to physical functioning of older adults in three Asian societies. *Research on Aging, 26,* 224-258.

# APPENDIX A NORMALITY PLOTS FOR WELL-BEING MEASURES

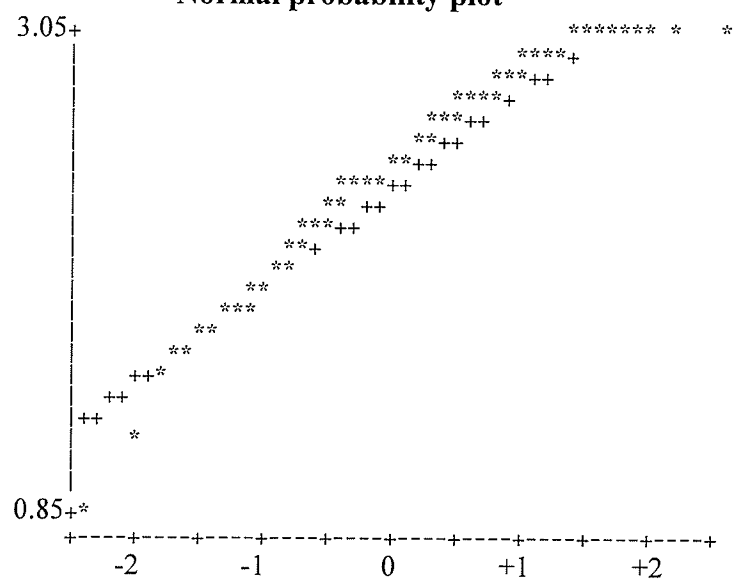
**CESD (depression) scores before transformation**



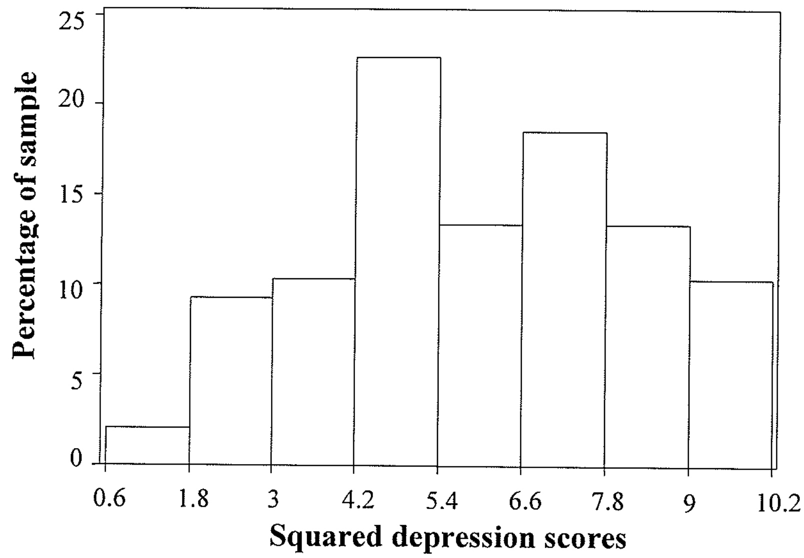

**Boxplot**



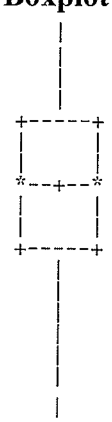
**Normal probability plot**



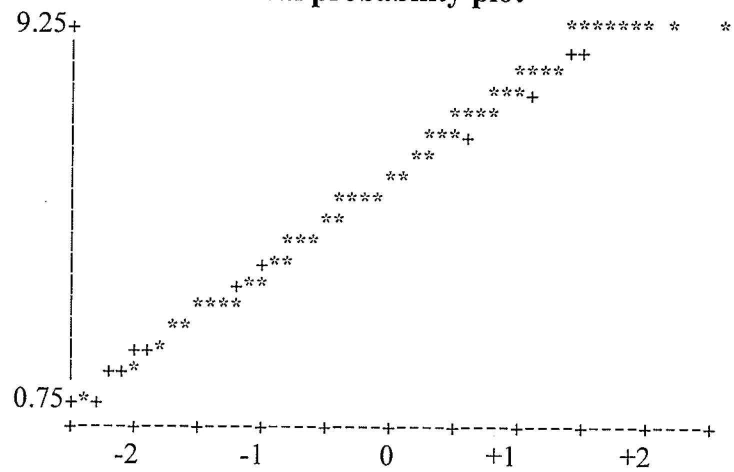
## CESD (depression) scores after transformation



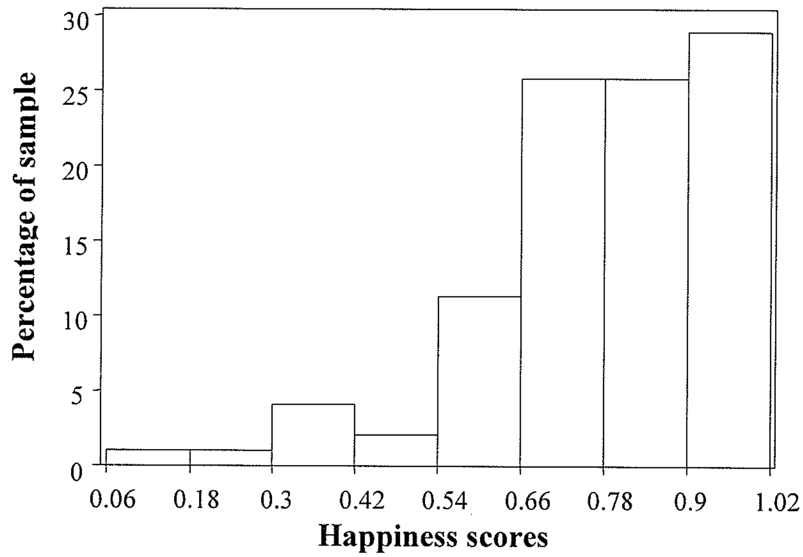

**Boxplot**



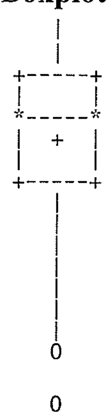
**Normal probability plot**



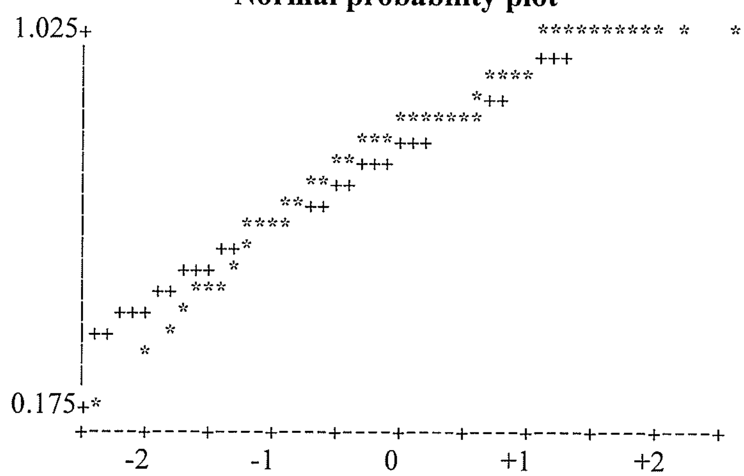
**SHARP (happiness) scores before transformation**



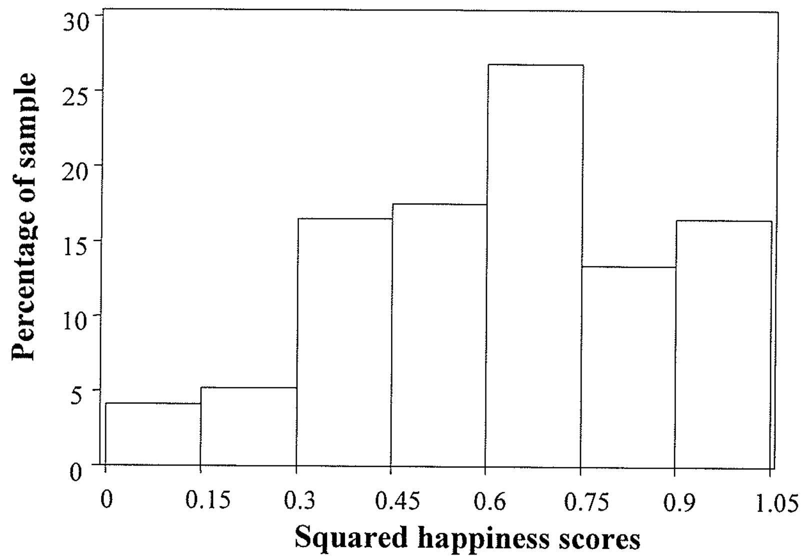

**Boxplot**



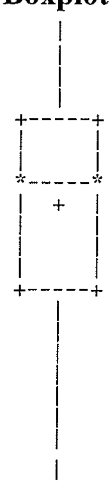
**Normal probability plot**



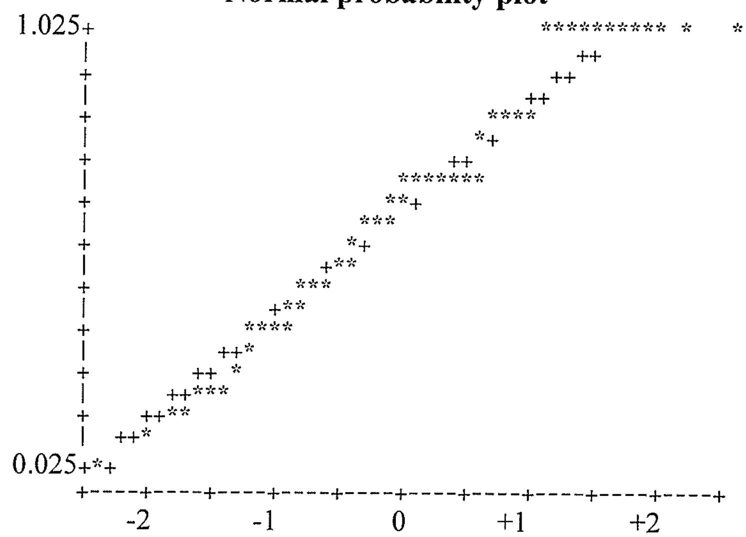
## SHARP (happiness) scores after transformation




**Boxplot**



**Normal probability plot**



# APPENDIX B ACTIGRAPH QUESTIONNAIRES

## ACTIVITY RECORDER DATA SHEET

---

PART A: GENERAL INFORMATION

STUDY ID: ______________________

Interviewer ID: ____________________

Actigraph Number: _____________________

---

PART B: VISIT #1

Ability to remove and replace activity recorder? (circle one) 0 No 1 Yes

Dominant hand? (circle one) 0 Left 1 Right

Place activity recorder on non-dominant wrist and record Begin Time (DDMMYY:hh:mm)

Left: __ __ __ __ __ __ : __ __ : __ __ Right __ __ __ __ __ __ : __ __ : __ __

---

PART C: VISIT #2

Remove activity recorder and record End TIME (DDMMYY:hh:mm):

Left: __ __ __ __ __ __ : __ __ : __ __ Right __ __ __ __ __ __ : __ __ : __ __

Reported activity recorder End Time (DDMMYY:hh:mm):
(RECORD ONLY IF ACTIGRAPH IS REMOVED BY PARTICIPANT)

Left: __ __ __ __ __ __ : __ __ : __ __ Right __ __ __ __ __ __ : __ __ : __ __

Aging in Manitoba

# ACTIVITY RECORDER INSTRUCTIONS

1. **Please continue your normal activities while wearing the activity recorder.** Try to forget you are wearing it, and just do what you normally would. This will help us to get a measure of your typical overall activity.

2. **If possible, wear the recorder at all times**, including when you sleep. However, the recorder is not waterproof, and so **if you bathe, please *take it off.***

3. **If you must take the recorder off, please**

    - Fill in the information on the reverse side of this instruction sheet.

    - Put the recorder back on the **same wrist** facing the same direction (with the arrow pointing to your elbow).

    - Make sure the recorder fits snugly enough so that it does not flop around on your wrist.

    - **If you are unable to put the recorder back on** after you have removed it, please **store it in a safe place** and **do not move it**.

---

## RECORDER PICK-UP

**The interviewer will come to remove the recorder on:**

**Date:**_________________________ **Time:** ____________

If you are unable to be home at that time, you may remove the recorder yourself as close as possible to the date and time written. Please see the reverse side of this information for instructions on removing the recorder.

**If you have any questions or concerns, please call the interviewer at the following telephone number:**

__________________________

STUDY ID: ___________

## REMOVING THE RECORDER

Take hold of the velcro strap and pull it off carefully. Set the recorder aside where it will not be disturbed until you put it back on, or until the interviewer returns to collect it. Be careful no to drop the recorder, as it can break.

If you must remove the recorder for any reason, please record the times and reasons in the boxes below:

Two examples are provided:

Example A: Someone took the recorder off at 8:10 in the evening to have a bath and put it back on at 8:40

Example B: Someone was unable to be home the day when the interviewer was scheduled to pick up the recorder and removed it at 2:05.

| | Time | | Reasons for Removal |
|---|---|---|---|
| | Off | On | |
| Ex. A | 8:10 PM | 8:40 PM | Had a bath |
| Ex. B | 2:05 | NA | Had to miss appointment with interviewer |
| 1. | | | |
| 2. | | | |
| 3. | | | |
| 4. | | | |
| 5. | | | |
| 6. | | | |
| 7. | | | |
| 8. | | | |