Measurement of Physical Activity and Associated Health and Functional Outcomes in Older South Africans

Measurement of physical activity and associated health and functional outcomes in older South Africans

By

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Declaration

I, Tracy Kolbe-Alexander, do hereby declare that the research trials presented in this these were conceived and executed by myself expect where otherwise indicated.

Neither the substance nor any part of the above thesis has been submitted in the past, or is being, or is to be submitted for a degree at this University or at any other university.

This thesis is presented in fulfilment of the requirements for the degree of PhD.

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List of Publications

Peer reviewed publications resulting from this dissertation

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Charlton KE, Schloss I, Visser M, Lambert EV, Kolbe T, Levitt NS, Temple N. Waist circumference predicts clustering of cardiovascular risk factors in older South Africans. *Cardiovascular Journal South Africa.* Jun-Jul;12(3):142-50, 2001.

Published Abstracts

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Abstract

The relationship between physical activity (PA) and chronic diseases such as hypertension, type 2 diabetes mellitus, coronary artery disease and hypertension has been well established. Even in older adults, regular physical activity has been associated with an overall reduction in morbidity and mortality. The strength of this association, and the nature of the dose response between PA and chronic disease and disability in older adults, depends in part, on the instrument or technique used to quantify PA. The instrument used, the domains measured (e.g. household and leisure time PA), and the time period for which PA is reported, may all impact on the estimation of PA energy expenditure. Further, there is a lack of standardization of the PA measurement and few such questionnaires are designed for older adults. The aim of the first study was to measure validity and reliability of two PA questionnaires, the Yale Physical Activity Survey for older adults (YPAS) and the short version of the International Physical Activity Questionnaire (IPAQ), in a group of South African older adults.

The YPAS includes measures of weekly energy expenditure (EE) for house- and, yard- work, care giving, exercise and recreation. The IPAQ questionnaire measures total time and energy expenditure during vigorous and moderate activity, in addition to walking and sitting. Both questionnaires were administered on two occasions to measure test-retest reliability in a group of older South African adults, representing socio-economically disadvantaged communities (men, N=52, 68±5.4 yrs, and women, N=70, 66±5.8 yrs). Data were obtained for criterion validity from accelerometers, which were worn for 7 days. Test-retest reliability and criterion validity were measured using Spearman's rank-order correlations. Limits of agreement were determined and concurrent validity was assessed using Kappa statistic.

Test-retest reliability results obtained for the YPAS ranged from r=0.44 to r=0.80 for men and r=0.59-0.99 for women ($P<0.0001$). Care giving was the most reliably recalled domain for women, and yard work for men. The IPAQ questionnaire yielded similar results for reliability, r=0.29 to 0.76 for men, and r=0,46 to 0.77 for women. Both groups best recalled sitting using the IPAQ, while vigorous and moderate activity had the lowest test-retest reliability. The relationship between the YPAS and motion counts was stronger for the men than the women. For the men, the strongest association was found between total weekly and exercise energy expenditure and total Computer Science and Applications activity monitor (CSA) counts (r=0.54 for both; $p<0.001$). Total weekly exercise energy expenditure and time spent in moderate activities as measured by the CSA monitor, were more strongly correlated

for women, (r=0.29, p=0.021), compared to the other domains of activity measured by the YPAS. Motion counts were significantly correlated to vigorous expenditure (metabolic minutes per week) as measured by the short IPAQ in men, where as vigorous MET min/wk and moderate MET min/wk were not significantly correlated to any of the CSA monitor parameters for the women. The strongest relationship was found for walking MET min/wk and total CSA counts for both the men and women (r=0.57;p<0.001 and r=0.42;p<0.001, respectively). Sitting MET min/wk were negatively and significantly associated with continuous CSA time and total CSA counts for both men and women, (r= -0.39, p=0.01); r= -0.40, p=0.001, r= -0.32, p=0.011, r= -0.35, p=0.005), respectively.

Thus, the YPAS and short IPAQ have comparable results for reliability and criterion validity. These results suggest that the choice between these PA instruments will depend largely on the intended application of results. Furthermore, the choice between instruments is dependant on the goals of the research. Because the YPAS includes the quantification of lower intensity activities that are commonly performed by older adults, such as housework and slow walking, it was chosen as a measure of current PA in the subsequent chapters of this thesis.

The majority of studies in which the relationship between PA and morbidity or health outcomes have been studied represent more well resourced communities in which leisure time PA tends to play an important role. More recently, Charlton et al. studied PA in a group of older South African adults living in a fishing village. Despite these older adults reporting low levels of PA throughout their lives, there was a significant association between lifetime occupational activity and systolic blood pressure. We were particularly interested in examining the effects of leisure time PA on measures of bone mineral density (BMD), which may be a common source of morbidity in older adults from more developed communities and also Caucasian populations. Consequently the main aim of our second study was to identify the association between lifetime and current physical activity and estimated BMD in a population of older Mixed Ancestry (Coloured) South Africans.

Further, despite evidence that physical activity can preserve mobility in older adults, there is a trend for activity levels to decline with increasing age. The decline in activity levels is especially pronounced in women, low-income groups and in persons with low education levels. We were therefore interested in the relationship between lifetime PA and current PA patterns in older South Africans who were from a low education and socio-economic status. Therefore a secondary aim of this research study was to measure lifetime physical activity patterns and to compare it to current levels of activity.

Estimated BMD and T-scores were measured using calcaneal ultrasound (SAHARA™) in 47 men and 105 women, mean age, 65 ±7 years. Lifetime PA was assessed retrospectively using a questionnaire comprised of three activity domains (household, occupational, leisure) during five age epochs (14-21; 22-34; 35-49; 50-64; $\geq$ 65 years) using a questionnaire developed by Kriska et al. Current PA was assessed using the YPAS. Peak bone strain units for each activity were calculated, based on impact loading of activities reported. Confounding factors such as BMI, smoking patterns and nutritional status were also quantified.

The men and women had similar mean estimated calcaneal BMD, 0.454±0.01 and 0.453±0.1g/m^2, respectively. The proportion of subjects presenting with apparent osteopenia or osteoporosis was similar in men and women (52% vs. 53% or 7% vs. 6%, respectively). Occupational PA during epoch 1 for men (r=0.35; p=0.034) and epoch 2 for women (r=0.24; p=0.033) was significantly correlated to estimated BMD. Occupational PA tracked throughout life in men and women with intra-class correlation coefficients of 0.96 (95% CI:0.94;0.98) and 0.96 (95% CI:0.95;0.97), respectively, suggesting that the individuals who were occupationally active when they were younger were more likely to remain active throughout life. Furthermore, current PA was associated with BUA in the women. Smokers had lower estimated BMD and T-scores than non-smokers (P<0.01). However, reported alcohol and calcium intake were not correlated to any of the ultrasound parameters. We therefore concluded that estimated BMD was weakly, but significantly correlated to occupational PA during the years of peak-bone mass accretion, which may be protective against accelerated bone loss in later life. From a public health perspective, these data highlight the importance of quantifying lifetime PA in all domains, including occupation.

Furthermore, the participants in our study reported current PA levels that were less than half of that previously reported in an American study. This finding was a cause for concern, as there is consistent evidence that increased levels of habitual physical activity improve quality of life and assist in maintaining functional independence in older persons.

Decreased functional ability or increased risk of frailty may contribute to the older adult's decision to apply for residency at homes for the aged for the purpose of long term care, at some point in their retirement years. In recent years these government subsidized homes for the aged have been encouraged to admit only those who are classified as frail because government subsidization is not as available for the functionally independent or individuals classified as "non frail". If South Africa as a country undergoing rapid demographic transition is following the trends of the other developed countries, structures and guidelines need to be formulated so as to ensure that both the current and future needs of the frail older adult are met with the limited resources available. Thus, the definition and measurement of "frailty" will become increasingly important when centres housing older adults apply for state funding.

Therefore we were interested in assessing the functional ability of older adults living in old age homes and those living freely in the community. Several studies that have enrolled subjects across a wide spectrum of physical performance have found consistently that physical performance is associated with prevalent disability or risk of incident disability. Research by Rantanen et al. found that severe motor disability was associated with lower physical activity, which in turn was associated with poor muscle strength. Socio-demographic factors that have been linked to increased disability include; lower socio-economic status, low levels of education, female gender and poor health associated with frequent hospital admissions. Therefore, the Xhosa speaking population group may be at increased risk of frailty and disability, since they are from a low socio economic status. In addition, there is a paucity of data on habitual PA and functional ability in this population group.

At present the South African Department of Social Services administers a questionnaire based assessment, Disability Questionnaire 1998 (DQ 98), to determine the degree of dependence / frailty of an individual and the urgency with which the applicant needs to be admitted to an old age home. The aim of our third study was therefore to measure the relationship between self-reported disability from the DQ 98 with objective measures of functional ability, and also with habitual levels of PA in community dwelling and institutionalised older adults.

Xhosa speaking men and women (>60 years) who were either community dwelling (n= 192) or institutionalised (n=29) and living in low socio economic townships in the Cape Peninsula, participated in this study. Several questionnaires were administered to each participant in addition to the DQ98, namely, activities of daily living (ADL), instrumental activities of daily living (IADL), self perceived health status, motor disability index, and current weekly physical activity (YPAS). The functional ability measures included the sit to stand test, static and dynamic balance, grip strength, functional reach, timed up and go test and the 8-foot walk.

More than half of the participants were considered independent on the basis of the DQ 98 score. However, there were no significant differences in the DQ 98, which failed to discriminate between those living in the community and those who were institutionalized.

Of the functional performance tests, only dynamic balance (r= -0.33), timed up and go (r=0.29) and gait speed (r= 0.29) were significantly associated with the DQ 98 scores. The strong relationship between these functional performance tests and ADL and IADL are corroborated in other studies. Therefore, these tests are able to play a role in determining current disability and functional impairment.

After performing a factor analysis, the scores from each of the seven functional tests were combined to generate a Functional Ability Index Score (FAIS). Therefore the FAIS includes multiple measures of functional ability, with scores ranging from zero to 28. A higher score represents greater functional ability and lower risk for frailty. The FAIS was able to discriminate between community dwelling and institutionalised participants and also between men and women. Therefore this instrument was more sensitive than the DQ98 for detecting those at high or low risk of frailty. In addition, the FAIS was significantly associated with ADL (r=0.52), IADL (r=0.44) and the DQ 98 (r=-0.34). The results suggest that self-report measures of disability should be used in conjunction functional measures, in order to provide a more comprehensive assessment of the older adult's degree of disability.

Furthermore, weekly PA was significantly associated with self-report measures and also with the functional tests. Of the self-report measures, IADL had the strongest association with weekly PA (r=0.51) followed by ADL (0.40) and the DQ 98 (r= -0.43). The individual functional tests that were significantly related to weekly PA were static balance (r=0.18), dynamic balance (r=0.40), grip strength (r=0.19), sit to stand (r= -0.15), timed up and go (r= -0.17), and gait speed (r=0.30). Furthermore, the FAIS was significantly associated with weekly PA, r=0.35. These findings underscore the potential benefits of habitual PA in delaying the onset of disability and frailty. As a result, encouraging older adults to increase the habitual levels of physical activities may contribute to preserving their functional status and also reduce the risk of mortality.

A secondary aim of this study was to compare two constructs of frailty with the FAIS and DQ 98 scores. Because cognitive function has been associated with increased risk of frailty, it formed the basis of our first construct. Those individuals scoring more than 15 for the 6-item cognitive function test, were classified as frail. The second construct was obtained from Chin A Paw et al., who classified those in the lowest quartile for both PA and BMI (PA+BMI) as frail. Nearly a third of our sample were classified as frail using the cognitive score construct and only six percent using the PA+BMI construct. The PA+BMI construct had a stronger relationship than cognitive score with the FAIS (r=0.47 versus –0.27), ADL (r=0.39 versus –

0.24), IADL (r=0.73 versus –0.34), and the DQ98 (r= -0.61 versus 0.34). The PA+BMI construct may be a superior measure to cognitive function alone, when trying to determine the risk of frailty and degree of disability among both community dwelling and institutionalised individuals. Despite the weaker associations between the cognitive construct and disability, those classified as frail using cognitive score, reported significantly more IADL disabilities and also had poorer performance for dynamic balance. Impaired cognitive function has previously been associated with increased likelihood of developing or worsening disability and also poor health status. Thus, this measure may contribute to determining IADL disability.

Another important finding was the association between decreased weekly energy expenditure and increased reported difficulties in performing daily tasks. Thus regular physical activity in older adults may assist in increasing or maintaining functional performance, thereby delaying dependence and disability.

Since functional ability is associated with increased impairment in ADL and IADL tasks, and decreased weekly energy expenditure, an attempt should be to maintain independence and thereby delay the onset of frailty. Subsequently, we investigated the effectiveness of a 20-week, low intensity community based exercise programme on both functional ability and health. Community-based exercise interventions may be more "culturally-sensitive" than institutionalised exercise programmes, and regular low intensity activity may encourage more independent living, which could delay the need for institutionalised health care. The aim of our final study was to determine the effectiveness of a 20-week exercise programme conducted at community centres in producing beneficial changes in physical functioning, muscle strength and endurance, balance, habitual levels of physical activity, self perceived health status and blood pressure of older adults.

Three community centres were selected: two were randomly allocated to the same 20-week, twice-weekly exercise program (EX; n=54) and a third to relaxation classes (control/CTL; n=21). All the participants were sedentary at baseline. Measurements at baseline, 10 and 20 weeks included field tests for anthropometry, balance, gait, upper and lower body strength, 6-minute walk test, blood pressure, activities of daily living, physical activity recall and self perceived health status.

Dynamic balance improved significantly in the exercise group (64 ± 28 sec at baseline to 43 ± 15 seconds at 20 weeks ($p<0.001$). In addition, a significant increase in lower body strength, as measured by the number of sit-to-stand repetitions in 10 s was observed in the exercise group ($p<0.001$). No significant changes occurred in these measures in the CTL group. In a sub sample of subjects who were hypertensive at the outset, exercise intervention was associated with a significant decrease in systolic blood pressure (n=26; 146 mmHg to 140 mmHg; p = 0.005) with no changes in the CTL group. Variables unaffected by exercise training were upper body strength, body composition and fat distribution, 20m walk, cardiovascular endurance and time spent in recreational activities. Therefore, a 20 week community-based, low intensity exercise programme improved dynamic balance and lower body strength in community dwelling older adults and improved blood pressure in hypertensive subjects. The ADL score, which has been linked to functional ability did not change significantly in this study population, and is largely due to the fact that most of the participants had a high functional status at baseline.

In conclusion, this thesis explored properties of PA questionnaires that may play a role in capturing the PA dose response in older adults. Current levels of PA are better measured using the YPAS questionnaire, compared to the IPAQ, because it includes low intensity activities commonly performed by the elderly. Although, current levels of activity in the mixed ancestry population were low, however, activity between the ages of 14 and 21 years over men and 22 and years for women, were associated with increased BMD. Furthermore, a large proportion of this population had low BMD scores, suggesting that physical activity, together with other intervention programmes could play a role in improving bone health among these older adults.

PA was associated with functional ability, which was in turn associated with reported difficulties in ADL and IADL. The DQ98, which was designed to determine the level of urgency for entry into an institution, was unable to discriminate between those who were community dwelling and those who were institutionalised. Conversely, the FAIS, was able to discriminate between these groups. Thus we suggest that both the DQ98 and FAIS be used to determine and individual's degree of disability and dependence.

Furthermore, we found that a low intensity community based PA intervention program improved functional ability as measured by the dynamic balance and sit to stand tests, in older adults. Moreover, systolic blood pressure was significantly reduced after the 20 weeks intervention, particularly among those with hypertension.

The findings of this dissertation underscore the importance of PA, for both health and functional ability in older adults from low socio-economic groups. This is relevant from a public health perspective, since encouraging older adults to become or remain PA may play a role in reducing their risk of frailty, improving functional performance and also assist in managing hypertension.

Abbreviations

PA	Physical activity / physically active
US	United States
YPAS	Yale Physical Activity Survey
PAR	Stanford 7-Day Physical Activity Recall
CHAMPS	Community Health Activities Model Program for Seniors
PASE	Physical Activity Scale for the Elderly
MET	Metabolic equivalent
VO_2	Oxygen consumption
MLTPAQ	Minnesota Leisure Time Physical Activity Questionnaire
IPAQ	International Physical Activity Questionnaire
LTPA	Leisure Time Physical Activity
DLW	Doubly Labelled Water
CSA	Computer Science Applications
RPE	Rate Perceived Exertion
ADL	Activities of Daily living
IADL	Instrumental Activities of Daily Living
CAD	Coronary Artery Disease
BMD	Bone Mineral Density
BMC	Bone Mineral Content
QUS	Quantitative Ultrasound
DXA	Dual x-ray absorptiometry
BUA	Broadband Ultrasound Attenuation
SOS	Speed of Sound
SI	Stiffness Index
TBBM	Total Lean Body Mass
LBM	Lean Body Mass
BMI	Body Mass Index
HRT	Hormone Replacement Therapy
BBT	Berg Balance Test
PPT	Peak Performance Test
FICSIT	Frailty and Injury: Cooperative Studies of Interventions Trial

EPESE	Established Populations for Epidemiologic Studies of the Elderly
WHO	World Health Organisation

CHAPTER 1

LITERATURE REVIEW

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1.1. Physical activity and health in older adults: An African Perspective

1.1.1. Introduction

The population of Africa is growing older, and the projected shift suggests that the number of adults reaching 60 years or more is expected to double in many African countries in the next 50 years [1] (www.census.gov/cgi-bin/ipc/). South Africa has the highest proportion of older persons in the Southern African region with nearly 7% of the population over the age of 60 years. This changing demographic profile is a consequence of the "epidemiological transition" described by Omran [2] as the "transformation of social, economic and demographic structures" that occurs in developing countries, often resulting in the consequent co-existence of both infectious and non-communicable diseases. As communities move rapidly through this transition, the burden of disease shifts to older adults and the often preventable, chronic diseases of lifestyle [3].

1.1.2. Burden of disease in Sub-Saharan Africa

This dual burden of disease is particularly evident in developing countries, including those found in Latin America, the Middle Eastern Crescent, Asia, the Pacific Islands, and Sub-Saharan Africa. In these countries, the probability of death in children under the age of 15 years is between 5 and 20%, mostly due to communicable diseases, malnutrition and peri-natal disorders [4]. However, at the same time in developing countries, the morbidity from chronic diseases, such as cardiovascular disease, diabetes and cancer, is increasing [4]. For example, the prevalence of non-insulin-dependent diabetes mellitus in developing countries has been estimated at just over 3% of the adult population ($\geq$ 20 yrs of age), and within the next 20 years, this prevalence is expected to increase by nearly 50%, compared to an expected 27% increased prevalence of Type 2 diabetes in developed countries [5].

South Africa and the Southern African region reflect an area undergoing the epidemiological or demographic transition. There is enormous cultural and socio-economic diversity, widespread unemployment, and rapid urbanisation. It is estimated that by the year 2010, for example, 70%-80% of the South African population will be urbanised. Within this region, communicable diseases are endemic. In South Africa, communicable diseases, maternal causes of death, peri-natal conditions and nutrition deficiencies were associated with 21% of deaths in adults. HIV/AIDS related deaths were 30% of all adult deaths in 2000 [6].

Conversely, chronic diseases of lifestyle in South Africa account for nearly 37% of adult deaths, and the majority of South Africans have at least one modifiable risk factor for chronic disease [6]. More specifically, conditions such as hypertension and diabetes in older South African adults are very common. For example, prevalence of hypertension ($\geq$ 160/95 mmHg or under treatment) in black South Africans (over the age of 65 yrs) living in urban and peri-urban communities has been found to be greater than 43% in men and more than 66% in women [7;8]. Similarly, older adults of Mixed Racial Ancestry from the Western Cape region have a reported prevalence of high blood pressure of 66.7% (95% CI: 57.3-76.1%) in men and 76.5% (95% CI: 68.3-84.7%) [9]. Moreover, those individuals with hypertension are generally poorly controlled [7;10]

Therefore, it is possible that older Africans are living longer, but with an increased burden of disease and disability. Furthermore, at least 92% of previously disadvantaged older South Africans have no medical insurance, yet 90% have annual medical expenses [1], highlighting the potential economic burden associated with chronic disease prevalence in these communities.

1.2. The economic costs of disease and physical inactivity in older adults

The prevalence of cardiovascular disease, and associated mortality increases with age [11] and has been identified as the largest cause of death worldwide [12]. However, those who participate in regular PA, have healthier cardiovascular profiles than those who are less or inactive [11]. Similarly, regular PA reduces the risk of metabolic syndrome, even after covarying for factors such as age, smoking and alcohol intake [13]. The increased prevalence of these diseases leads to increased health care costs [11] and therefore places an additional pressure on health care systems in developing countries who are faced with a quadruple burden of disease (communicable, HIV/AIDS, non-communicable, accidents and violence) [6].

It has been widely recognized that older adults consume a higher proportion of medical expenditure compared to other age groups. Furthermore, the prevalence of chronic diseases of lifestyle increases with age [14] and the estimated medical costs of coronary heart disease and diabetes are approximately \$51.1 and \$44.1 billion annually in the United States [15]. Therefore, the potential of PA for producing health benefits, which is associated with medical savings exists, particularly among a population of older adults. In fact, Perkins et al. reported that the lifetime costs of inactivity were $1900, compared to an expenditure of $2900 for those who smoke [16]. Since a greater proportion of the population is sedentary, compared to those who smoke [16], the potential benefits of becoming physically active are substantial.

The relationship between PA and medical costs was investigated by Pratt et al. who performed a cross sectional stratified analysis of the 1987 National Medical Expenditures Survey in the US [15]. The sample was comprised of men (n=8 975) and non-pregnant women (n=11 006) who were older than 15 years. Costs associated with medical care were reported by the participants and also confirmed in a survey conducted with medical providers. Those who were classified as physically active participated in at least 30 minutes of moderate or vigorous activity for three or more days per week. In addition, a sub group of participants was created incorporating those who reported physical limitations when performing moderate intensity activities. The annual medical expenditure for those classified as physically active was significantly lower than those who were sedentary, $1242 vs. $2277 [15]. Even when excluding those who were limited by chronic health problems, the annual cost was $300 more in the sedentary group. Similarly, in the older adult group, PA was associated with lower direct medical costs, particularly for women over the age of 54 years. Conversely, PA in men older than 75 years was actually associated with greater direct medical expenditure than their less active counterparts [15]. The lack of association may be due to an increased risk of injury from PA in this age group and also possibly due to a 'healthy survivor' effect.

While Pratt et al. [15] included men and women older than 15 years in their study, Perkins et al. [16] measured the association between walking and economic benefits among those aged 55 years and older. The sample comprised of men and women who were chronically ill and also from a lower socio-economic status. Walking was chosen as a measure of PA, because it is the most commonly performed PA among older adults [16]. Total walking time was divided into five categories: none, 1-29 minutes, 30-59 minutes, 60-119 minutes and 120 or more minutes per week. A linear relationship was present between the time spent walking and number of hospital and emergency room visits. However, primary care visits were not associated with increased time spent walking. Those walking more than 60 minutes per week, experienced significant savings for total medical expenditure, inpatient and emergency room related costs. Although this group had lower outpatient costs, they were not significantly different to those who walked less than 60 minutes per week. Even the participants who walked 1-29 minutes per week, had a significantly lower risk of hospital stays, compared to those who did not walk. Thus, the benefits associated with PA start from as little as several minutes of walking per week, although the greater benefits are associated with walking more than one hour per week [16].

Tsuji et al. who investigated the relationship between walking and health care expenditure prospectively over a four-year period [17] observed comparable benefits associated with walking. The Japanese participants categorized their daily walking as less than 30 minutes, 30-60 minutes or more than 60 minutes [17]. Similar to Perkins et al. [16] a linear relationship between time spent walking and medical costs was demonstrated in this study. After adjusting for confounders such as age, gender, self rated health and chronic diseases, those who walked less than 30 minutes per day spent £1180 per month which was considerably more than the £97spent by those who walked more than 60 minutes per day [17]. There was no associated benefit with walking 30-60 minutes per day, compared to those walking less than 30 minute per day. Conversely, the participants who walked more than one hour per day had significantly lower accumulated medical expenses over the four-year period compared to those who walked less than an hour per day. Furthermore, those walking less than 30 minutes per day incurred 16% higher medical costs associated with hospital care, compared to those who walked more than one hour per day [17].

One of the strengths of the study conducted by Tsuji et al. is that it evaluated PA and medical costs over a four-year period, and subsequently concluded that the medical savings associated with PA will increase over time [17]. This conclusion was reached based on the finding that most of the cost benefits associated with walking occurred after 1.5 years, and the gap in expenditure between the active and sedentary participants grew for the remaining 2.5 years [17]. Furthermore, the Japanese who participated regularly in moderate and strenuous sports experienced 25% medical savings.

Even though walking was associated with reduced health-related expenditure, Tsuji et al. [17] were unable to determine whether increased PA or walking among those who were previously sedentary, would result in reduced expenditure. The association between changes in physical activity levels and healthcare costs were examined prospectively in men and women (n=2393, mean age 63 ± 5 years) who were enrolled in a Minnesota health plan [14]. The participants of this study were classified as; active at baseline and inactive at follow up, or inactive at baseline and active at follow up, or inactive at both visits, and lastly, as active at both visits. The results of this study showed that even those who increased their levels of PA from zero to one or two exercise sessions per week, lasting 30 minutes or more, experienced medical savings ranging from $1200 to $1900, compared to those who were inactive at both visits [14]. Furthermore, the participants who increased the frequency of PA sessions from 0-1 to more than three times per week, had even greater savings over the two year period, $2200 ($p< 0.01$), than those who remained inactive. Based on these findings, the inclusion of PA into one's lifestyle will result in cost savings for those over 50 years of age [14]. These savings are evident after only one year of increased activity levels. In addition, Martinson and co workers suggest that the medical savings that are likely to occur with increased PA, are greatest in older adults [14].

In unpublished data from a cross sectional cohort of South African older adult men (N=2568), currently members of a private medical insurance company, and who are registered for some form of chronic management, self-reported physical activity levels were also associated with reduced expenditure in those between the ages of 50 and 59 years ($P < 0.05$). However, there were no significant differences in medical expenditure for those older than 60 years (Kolbe-Alexander, Cowling K. and Lambert, EV, unpublished observations).

Therefore, the associated medical savings that are likely to occur with increasing levels of PA, highlight the need to promote this behavior, particularly among older adults. However, in order to effectively encourage older adults to include PA into their lifestyles, it is important to understand the barriers to regular activity in this age group.

1.3. Prevalence and determinants of Physical Activity in older adults

1.3.1. Prevalence of physical activity in African older adults

Although the role of PA in the prevention and attenuation of chronic diseases of lifestyle is widely recognized, even in older adults, there are little data on the prevalence of physically active lifestyles in older adults in Sub-Saharan Africa. There are also few studies that have attempted to link physical activity to health outcomes or morbidity in this population. What data are available are largely derived from regional, cross-sectional risk factor surveys, and suggest that persons over 55 years of age have the lowest levels of self-reported moderate and vigorous physical activity. For example, more than 30% of women and 40% of men, surveyed in a Black urban community in Cape Town, reported being completely sedentary in their work and leisure time [8]. Similarly, 45% of older women and more than 80% of older men from a peri-urban community in the Western Cape also had activity levels in the lowest quartile [18].

In a recent follow-up study of older South African adults from historically disadvantaged backgrounds, the Yale Physical Activity Survey for Older Adults (YPAS) was used to describe patterns of weekly activity spent in housework, gardening and yard work, care-giving, exercise and recreation [9]. Results from this study suggest that these South African seniors spent an average of 2583 kcal/wk ($\pm$ 3027 kcal/wk) in physical activity, 65% less than that reported in a sample of North Americans of the same age [19]. Moreover, in this study [19], and in a more recent study in a similar peri-urban community of older South African adults [20], current levels of physical activity were dissociated from various indicators of morbidity such as blood pressure, waist circumference, and BMI, as well as, prevalence of hypertension, diabetes and hypercholesterolaemia. On the other hand, moderate lifetime occupational PA levels, in the same sample, recalled for the ages from 14-49 yrs using a historical activity questionnaire, were significantly and inversely associated with current systolic blood pressure, $r = -0.24$, $P < 0.05$ [20].

These data suggest that in countries like South Africa, PA levels decrease with increasing age. This decrease in physical activity with age has also been well documented in developed countries [21-24]. Further, the failure of association between current physical activity and morbidity, and even mortality [9;20;25;26] in older adults from transitional communities, may be explained, in part, by a 'healthy survivor' effect. Persons who reach ages 65+ in developing countries may be more resistant to chronic diseases and generally 'hardier'. It may also be related, in part, to difficulty in quantifying physical activity energy expenditure. A recent study measuring 'time-use' in older persons of KwaMashu township in the Natal region of South Africa showed promising results for the description of daily activities, including the context in which these activities took place [27]. This methodology may be of value in further attempting to quantify physical activity levels in these communities, and to plan appropriate interventions in this target group.

In rural African communities, such as those found in western Kenya, physical activities the older adult are likely to undertake include: subsistence farming, collecting firewood, washing clothes and child care. Participation in these activities continues until individuals are considered too frail rather than too old [28]. In another example, in a rural Ethiopian community of the Rift valley, low BMI and severity of illness, as well as seasonality, influence PA energy expenditure [29] PA is the means by which individuals provide nutritional support for themselves and their families, without which they may fall ill, and the vicious cycle of under-nutrition and disease continues. These findings highlight the important interactions between physical activity, health and nutritional status in older adults from developing and more especially, subsistence communities.

1.3.2. Determinants of PA in older adults

PA patterns may vary for men and women since women are more likely than men to report that they limit or avoid physical activity [24;30]. Jones et al. reported that men were more active than women across the lifespan, spent more time participating in sports and leisure activities and were more likely to adhere to exercise programmes [23]. This is supported by Jacobs et al. who compared results from ten physical activity questionnaires among older adults and found that each questionnaire characterised men as more active than the women [31]. Furthermore, the men were more physically active than women in light, moderate and heavy intensity physical activities, whereas the women had a higher prevalence of participation in household activities [31].

Consequently, the domains (e.g. household, leisure, occupation) of physical activity measured may influence the determination of the prevalence of inactivity. Heavy housework is often the most the most frequently reported activity among women, particularly those from lower socio-economic groups with physical exercise (such as fitness classes, swimming or jogging) and brisk walking reported less frequently [22;32]. In fact, over two thirds of British women aged 60-74 years met PA recommendations when household activity was included, however, the prevalence decreased to 21% when household activity was excluded [22]. In a separate paper by Friedenreich et al., the average number of hours spent in total weekly activity among older (mean age, 61.2 years) Caucasian women was 55.7 hours [32]. More than half of this time was spent in household activities (29.8 hours) with the remaining time spent in occupational (22.3 hours) and sports / exercise activities (3.7 hours). Furthermore, these researchers found that their participants spent, on average, 18.8 ± 11.3 hrs/wk in light intensity activity, 22.4 ± 14.9 hrs/wk in moderate activity and only 5.8 ± 10.6 hrs/wk in heavy activities after summing lifetime occupation, household and sport /exercise related activities [32]. These findings underscore the importance of defining the criteria used to measure and report PA patterns, specifically in the older adult population, who are less likely to be employed and more likely to spend their time in household and leisure related activities.

Evenson et al. conducted a prospective study (6 years) in African American and Caucasians aged 45-64 years to investigate the influence of retirement on physical activity levels using the Baecke questionnaire [33]. For those in physically active occupations, retirement may result in a decline in habitual PA levels [33], however the additional "free time" presents an opportunity for increased leisure related PA. In the study by Evenson et al. [33] both the men and women who retired during the 6 years became significantly more physically active. Although the retirees showed greater increases in walking, there was a simultaneous increase in time spent watching television. Therefore the benefits that could be achieved from regular PA may be offset by increased "compensatory" sedentary behaviour such as watching television. Retirees who participated in sport or exercise at baseline were more likely to maintain their behaviour than those who continued to work [33]. For those retirees who were inactive at baseline, retirement resulted in increased sport and exercise participation, except for African American women. Therefore a change in work status has favourable impact on PA status among men and women older than 45 years.

Other factors that may influence PA patterns and prevalence include: ethnicity and urbanisation. Indeed, in studies conducted in the US, African American women reported the lowest participation in sport, while Caucasian men reported the highest. Similarly African American men had the lowest prevalence of leisure time PA, and Caucasians women the highest [33]. Young et al. measured physical activity in older adults and reported that their participants expended 3657 kcal/wk (median) using the YPAS questionnaire and 34.1 kcal/day when using the Stanford 7-day physical activity recall (PAR), which is indicative of a sedentary lifestyle [34]. African Americans reported lower median energy expenditure in both the YPAS and PAR questionnaires, than the non African American subjects. However, the African American participants spent more time in light housework, heavy home repair, and meal preparation and childcare-related activities, whereas their counterparts spent more time in heavy housework, yard work and walking. Therefore, differences in activity patterns in these groups may largely reflect differences in socio-economic status and culture.

Evenson et al. investigated the prevalence of vigorous activity participation among a group (n=71 837) of women who were part of the Women's Health Initiative Observational Cohort Study (aged 55-79 years) [21]. They found that current participation in vigorous activity at least three days per week was similar among Blacks (13.2%), Asian Pacific Islanders (16.6%), Hispanics (13.4%), American Indians (10.5%) and Whites (14.8%). Even though Asian / Pacific Islanders reported the highest current PA; they had the lowest prevalence of PA at 18, 35 and 50 years [21]. Jones et al. investigated the proportion of American adults meeting the American College of Sports Medicine (ACSM) guidelines to accumulate moderate activity on most days of the week and found that Caucasians reported greater participation than Blacks (33% vs. 30%) and Hispanics (25.9%) [23]. Similarly, Wolf et al. found that African American women reported less activity in both self-report physical activity questionnaires and activity diaries than Caucasian women (mean age 39 years) [35].

Furthermore, rural women, particularly American Indians, or African Americans, were more sedentary than Caucasians [36]. Inactive rural women tended to be older, less educated, less likely to see others exercising and received less social support than those who were regularly active [37]. The main barriers to PA reported by rural women were lack of social support, fear of injury, safety and care-giving duties. These barriers are even more pronounced in populations where there tends to be higher rates of poverty, greater distances to travel for health care and other services, and lower levels of education [37]. Conversely, urban areas have more sidewalks, streetlights, and greater access to exercise facilities [37]. The barriers reported by urban women were lack of time and energy, fatigue [36] and lack of transport as well as financial status [38]. Sedentary persons living in urban areas tended to be older, had greater perceived barriers to leisure time PA, less educated and received less social support than those who were physically active [37].

Other perceived barriers to participation in middle-to-older-age women (55-64 yrs) are the absence of an exercise partner, fatigue and health problems [24]. However, for women older than 74 years, the main barrier to PA was health and functional problems, as well as fear of falling [24]. Thus, participation in vigorous activity was lowest among those who rated their health as "fair" or "poor" (4-6%) compared to those who had good or excellent health (24-27%) [21]. This is supported by Lawlor et al. who found that poor health were associated with lower levels of PA [22]. Furthermore, older adults who were more likely to drop out of a supervised exercise intervention had more co- morbidities and symptoms of disease than those who remained physically active [39].

Other factors influencing a physically active lifestyle are smoking and marital status. Current participation in vigorous activity was reported more frequently among older women who had never smoked or were ex-smokers [22;33]. Marital status has also been related to reported levels of PA. Black women who were never married reported the highest prevalence of vigorous activity. Conversely, Asian / Pacific Islander and Caucasian women who were never married reported the lowest prevalence of vigorous activity compared to the unmarried Black women [21]. Thus the relationship between marital status and PA may differ, in part, depending on the socio-cultural context.

In summary, female gender, older age, lower socio-economic status and levels of education, are among the factors associated with reduced levels of PA. In addition, the socio-culture context influences levels of activity. When determining whether the older adult is meeting minimal PA recommendations, it is advisable to include domains such as housework and yard work, as these are activities that are frequently reported in this population [22]. Furthermore the intensity of regular activity tends to decline with age, and light intensity activities may need to be included in the calculation of total energy expenditure for this age group.

There is a paucity of data focusing, in particular, on PA patterns of older adults, in communities undergoing epidemiological transition. In Sub-Saharan Africa, experiencing the HIV/AIDS pandemic, the functional capacity of older adults is likely to be of increasing importance, as they play a more significant care-giving role for young children, whose parents may have died. Thus, there is a need to determine which instrument best captures habitual activity in these populations. Measuring PA in older adults is determined by a number of variables, which will be discussed in the next section of this literature review.

1.4. Measuring physical activity in older adults

1.4.1. Physical activity questionnaires

PA levels of exposure and prevalence in epidemiological studies are best-measured using questionnaires as they are cost-effective and require little in the way of technological support [40]. However, few questionnaires have been validated in the older adult population [19] and those developed for younger participants may not be suitable for use in older adults.

One of the more important factors affecting reliable reporting when using questionnaires is the logic of the questions asked, rather than the amount of detail required [31]. For example the College Alumnus Questionnaire only has three questions pertaining to stair climbing; number of blocks walked per day and recreational activities, yet it is related to all-cause mortality and coronary heart disease [31]. Thus, the reliability and validity of simple questionnaires are occasionally higher than those that are longer and more complex [41]. This is supported by Shephard who reported that the inter-test correlations between scores (e.g. weekly energy expenditure, kcal/week, or rating of activity level) obtained from complex or lengthy questionnaires (e.g. Tecumseh LTPA) are low, and range from r=0.14 to r=0.41, compared to r=0.93 for the simpler Godin questionnaire [41]. However, it is important to note that longer questionnaires are more likely to capture variations in weekly physical activity to the comprehensive nature of the questionnaire. Consequently, simpler instruments are useful when quantifying general levels of physical activity in large epidemiological surveys, whereas the longer and more complex questionnaires are preferred when measuring sensitivity to change in physical activity patterns such as after an intervention. In addition to complexity, the sequential administration of each questionnaire may also affect the results for studies investigating the criterion and concurrent validity of one questionnaire with another, [35].

The following section of the literature review will provide examples of questionnaires that have been used in the older adult population. In addition, the reliability and validity of these questionnaires will be discussed. Table 1.1. describes questionnaires that have been used in middle aged and older adult populations.

1.4.1.1. Yale Physical Activity Survey (YPAS)

DiPietro et al. developed the Yale Physical Activity Survey (YPAS) for older adults in 1988 [19] (Table 1.1.). The researchers first interviewed a cross-sectional sample of older adults (n=222, 71 ± 6.8yrs) to establish the types of activities most commonly performed by older adults, as well as the factors that limited participation in physical activity or were considered to be barriers.

The YPAS is interviewer-administered and is divided into two sections in order to calculate eight indices of physical activity. For the first section, participants are questioned on the frequency and duration of participation for activities related to housework, yard work or gardening, care giving, recreation and exercise, for a usual week during the current month. Time spent in each of these domains is summed to calculate hours per week of PA. In addition, time spent in each activity is multiplied by an intensity code, to calculate kcal/min, which is then summed to estimate kcal/week.

For the second section of the YPAS, participants are required to report their participation in vigorous activities, light intensity walking, general moving about, standing and sitting. Participants also report on any seasonal variation that may occur for each of these activities. First the frequency and duration (min) for each of these activities are multiplied, and then further adjusted by a weighting factor. Vigorous activities are given a weighting of five, leisurely walking four, the moving index is weighted as three and the standing and sitting index are weighted as two and one respectively. These indices are then summed to create the total / summary index.

In the original study, DiPietro et al. reported test-retest reliability [19] (Table 1.2). There were no significant differences in mean activity hours between the first and second administration of the YPAS. The Pearson product moment correlations revealed strongest correlations for the exercise and recreation domains, which were higher intensity activities, while the lower intensity activities such as housework and gardening had weaker test-retest reliability. The correlation coefficients for total time spent in activities and energy expenditure in kcal/week were r=0.57 and r=0.58, respectively. For the various indices, the test-retest correlation was strongest for the total / summary index (r= 0.65) and weakest for sitting (r = 0.42).

The twenty-five subjects participating in the validation study wore a Caltrac motion sensor on the left side of their waist for 2.5-week days. None of the indices or scores from the YPAS were associated with the Caltrac motion scores, although the total /summary and leisurely walking index approached significance (Table 1.3). Two and a half days may not be representative of an entire week, and this together with the small sample size, which resulted in decreased statistical power, may explain the lack of association between reported and measured energy expenditure. Older adults may perform activities classified as moderate or vigorous at a lower intensity than younger adults [42], which may make the interpretation of a linear relationship between motion counts and physical activity recall more difficult to interpret. Furthermore, the natural variability in weekly energy expenditure and physical activity is likely to be reflected with the Caltrac measures, whereas the YPAS may not be sensitive to these changes.

The summary and vigorous indices were associated with VO_2 max, r=0.58 and r=0.60, respectively, however, total weekly activity time and kcal/week were not associated with VO_2 max, nor BMI and percentage body fat [42]. Conversely, Young et al. reported a significant relationship between the YPAS summary, moving and standing indices with VO_2 max and BMI in a group of older adults (n=59, mean 66.5 ± 5.2 years) [34]. VO_2 max was not correlated with the vigorous and summary indices in the study by Young et al. [34]. Subjects' mean weekly PA energy expenditure was approximately half that of those from the original validation study of DiPietro et al. indicating that they were mostly sedentary. Therefore, Young's participants were more likely to perform lower intensity activities, which may explain, in part, the generally poor association with the vigorous indices. Despite the apparently lower levels of activity than found by DiPietro et al., they concluded that the global and vigorous activity indices measured using the YPAS captured the intended dimensions of activity in this population [34]. These findings suggest the YPAS can be used in older adults with varying levels of PA.

A further validation study for the YPAS compared reported PA to that of doubly labeled water (DLW) in a group of men and women mean age 66 and 67 years, respectively [43]. The reported energy expenditure was not significantly different to that reflected by the DLW, suggesting that this tool accurately quantifies physical activity in groups of older adults. However, these researchers suggested that the YPAS might not be the appropriate tool to measure PA before and after interventions among older adults, based on the wide limits of agreements that were observed using the Altman Bland analyses [43]. Conversely, Young et al. measured PA using the YPAS before and after a 12-week intervention, and found that the change in the YPAS dimensions were all in the expected direction and correlated with changes daily energy expenditure [34]. Although few of the correlations between the YPAS indices and PAR measures were significant [34], the YPAS moving index was significantly related to the PAR's change in daily energy expenditure and time spent in moderate activity. Thus the ability of the YPAS to track changes in habitual PA warrants further investigation.

In addition, as the questions for the first part (total hours and kcal/wk) of the YPAS were strongly associated with those from the second part (indices), the original authors [19] suggested that they might be substituted for each other in future research studies since the same activity construct is being measured.

1.4.1.2. Community Health Activities Model Program for Seniors (CHAMPS)

The CHAMPS questionnaire was developed to measure changes in PA patterns affected by the physical activity intervention among older adults [42]. The questionnaire takes approximately 15 minutes to complete and may be self-, telephone- or interviewer-administered. Participants report the frequency and duration of activities for a typical week in the past month for light, moderate and vigorous activities (Table 1.1). Six categories of participation are provided to facilitate recall, namely, less than 1 hour per week, 1-2.5 hours per week, 3-4.5 hours per week, 5-6.5 hours per week, 7-8.5 hours per week, and 9 or more hours per week. The four CHAMPs scores are comprised of estimated weekly kcal and frequency for both moderate (3 METS or more) and higher intensity activities, as well as "all" activities (sum of activities requiring less than 3 METS, with those of moderate and vigorous intensity activities) [42].

This questionnaire has been found to be sensitive to changes in PA patterns after a 6 and 12-month intervention program for older adults [42]. This is similar to the YPAS that is able to reflect changes in habitual physical activity patterns after a three-month moderate intensity aerobic exercise intervention.

Reliability of the CHAMPs questionnaire has also been assessed; by having the participants complete it on two occasions, separated by two weeks. The test-retest reliability for total energy expenditure was r = 0.62 and r = 0.76 for moderate and vigorous intensity activities, respectively, for the total sample (mean age, 75 years). The reliability was higher for males (r = 0.69 vs. r = 0.62) and also for those aged 75 years and older (r = 0.59 vs. r = 0.62). The relationship between moderate activities and gender and age were stronger than that for "all" activities for test-retest reliability. Reliability was comparable to that of the YPAS (r=0.58) questionnaire.

1.4.1.3. Physical Activity Scale for the Elderly (PASE)

Similar to the YPAS, the PASE measures weekly energy expenditure in household, occupational and leisure time activities for the 7 days preceding the interview, and takes approximately 5 minutes to complete. Participants are required to report the time spent in household, gardening and care-giving activities as well as walking, and light – moderate and heavy / strenuous leisure time activity [42] (Table 1.1). The total time spent in each activity per week is recorded, and multiplied by a weighting factor. The weighting of each activity was derived using a previously developed regression analysis, which includes data from the Caltrac monitor and MET values of activities recorded in an activity diary. The reliability of the PASE questionnaire is similar to that of the CHAMPS questionnaire, r=0.75. This questionnaire has been validated amongst 222 men and women, younger than 65 years (Table 1.2). Unlike the YPAS and CHAMPS questionnaires, the PASE questionnaire was not sensitive to change after a 12-month moderate intensity endurance and strength training programme in older women [42]. However, the PASE questionnaire was sensitive to changes in physical activity after a 6-week physician counseling intervention [42] Indirect evidence of the validity of the PASE questionnaire has been demonstrated in that reported levels of PA by community dwelling older adults have been significantly associated with self-reported health status, grip strength, static balance and leg strength.

1.4.1.4. Stanford 7-day Physical Activity Recall (PAR)

The strength of the PAR is that this interviewer-administered questionnaire has been used in numerous research studies, across different ethnic groups, including those investigating PA patterns of older adults [34]. The participants are required to report the number of hours of the previous week that were spent in hard, very hard and moderate activities as well as time spent sleeping (Table 1.1). Light intensity activities are calculated by subtracting the total hours of reported activities from 24. Each activity level is assigned a MET value that is multiplied by the number of hours spent at the level per day and is then summed to calculate total kcal per kilogram body weight per day. The MET values are as follows; sleep – 1 MET, light activity 1.5 METs, moderate activity 4 METs, hard activity 6 METs and very hard activity 10 METs.

Jacobs et al. compared the test-retest reliability of the PAR with other questionnaires among predominately Caucasian and college educated men and women (20-59 years old) [31]. Although the women participating in this study had lower levels of participation for moderate and very hard activity, the test-retest reliability was stronger for the men, r=0.33 vs. r=0.01 and r=0.51 vs. r=0.13. The test and retest was separated by one month, and the lower correlation coefficients obtained for reliability may have been related to normal variance in PA, as the PAR is designed to measure weekly activity [31].

One of the first studies evaluating the validity of the PAR was conducted in men (34 to 69 years) participating in a cardiac rehabilitation program [44]. When comparing the PAR to daily PA diaries, total daily energy expenditure for the PAR was significantly associated with self report PA, r=0.81, p<0.001 [44]. More recently, Young et al. reported significant associations between VO_2 max and daily energy expenditure, as well as with moderate PA [34]. This is a similar finding to that reported in Lamb and Brodie, where VO_2 max and body fat percentage were significantly associated with the PAR's energy expenditure after a six month PA intervention, r=0.33; p<0.05 and r= -0.50; p<0.001, respectively [44]. Furthermore, the PAR has been shown to track changes in PA, as energy expenditure increased significantly in a sample of previously sedentary men participating in a year long exercise program [44;45]. These results support the use of the PAR, even though is complex to administer and requires extensive interview training, as it has been previously shown to be both reliable and valid, and can track changes in PA behavior. Furthermore, this questionnaire has been shown to be sensitive to change as previously sedentary individuals participating in a year long intervention study reported significantly greater energy expenditure at one year compared to baseline measures [44]. However, the questionnaire was not designed to be sensitive to changes in physical activity for older men and women [46].

1.4.1.5. Minnesota Leisure Time PA Questionnaire (MLTPAQ)

This questionnaire was developed to test the hypothesis that exercise sufficient to provide a training effect plays both a preventative and protective role against coronary artery disease [44]. Subjects are required to indicate which leisure time activities they participated in during the past year, after which an interview establishes the number of months the activity was performed, as well as the frequency per month and duration of each session. Energy expenditure is expressed as kcal/min and also as an Activity Metabolic Index (ATI), which is calculated from intensity codes. Furthermore indices of light (<4 kcal/min), moderate (4-5.9 kcal/min) and heavy (≥ 6 kcal/min) are calculated [44]. Reliability of this questionnaire was investigated over a 5-week period in a group of 140 participants (men and women) 25 to 74 years, and also a 2-week period among 150 men aged 41-64 years. The five week test-retest showed correlations of r=0.88 (total LTPA), r=0.79 (light intensity LTPA), r=0.86 (moderate intensity LTPA) and r=0.82 (heavy intensity LTPA). The two week test-retest correlation coefficients were slightly weaker r=0.79 (total LTPA), r=0.82 (light LTPA), r=0.73 (moderate LTPA) and r=0.69 for heavy LTPA scores.

The validation of the MLTPAQ among 175 males aged 36-59 years showed significant correlations between exercise duration in a graded treadmill test and total LTPA (r=0.41) and heavy LTPA (r=0.44) [44]. However in a separate validation study among relatively sedentary males the associations between exercise time and total LTPA and heavy LTPA were weaker, r=0.08 and r=0.11, respectively. When comparing reported activity to a motion sensor worn at the waist and ankle, only the measurement from the waist was significantly associated to activity (r=0.69) [44]. More recently, Starling et al., measured the validity of the MLTPAQ using both DLW and the Caltrac motion sensor in a group of older men and women 45-84 years old [43]. These researchers found that the MLTPAQ underestimated daily energy expenditure in both men and women by 62% and 56%, respectively. The under-estimation of energy expenditure was, in part, attributed to the MLTPAQ focusing on team sports and higher intensity activities which are seldom practiced by older adults [43].

1.4.1.6. International Physical Activity Questionnaire (IPAQ)

The IPAQ is an interviewer or self-administered questionnaire that was developed to compare PA patterns across different countries among adults 18-65 years old [47]. There are two versions of the questionnaire, the long IPAQ and short IPAQ, and each of these had two versions in which participants either reported their "usual weekly" or "past week" physical activity patterns (Table 1.1). Only activities lasting longer than 10 minutes are recorded. The short IPAQ contains information on time (longer than 10 minutes) spent in moderate and vigorous activities and walking, including usual walking pace. In addition, the total number of hours spent sitting in a week and weekend day are recorded. The long IPAQ is a more comprehensive tool containing information on weekly activities in household and yard work activities, occupational activity, transport, leisure time physical activity and sedentary behavior. Participants from 12 countries answered both the long and short IPAQ twice, 3-7 days apart, in order to assess its reliability [47].

Spearman rank order correlation coefficients for repeatability were strongest for the USA sample (r=0.96) and weakest for the rural sample in South Africa (r=0.46), with most of the sites having good reliability (pooled repeatability coefficient, r=0.81). Similarly, the short IPAQ also demonstrated good reliability, r-values ranging from r=0.88 in the USA to r=0.32 in the rural South African sample (pooled r=0.76). The reliability coefficients for the telephone administered and self-administered version of the questionnaires were r=0.88 and r=0.96, respectively for the USA sample. Both South Africa and Guatemala, which were considered developing countries, used the interviewer-administered version of the IPAQ, where the reliability of the long IPAQ was 0.79 and 0.85 for these two countries. Furthermore, the rural participants from both South Africa and Guatemala yielded lower test-retest correlations than the other centers, suggesting that urbanization influences the reliability of the IPAQ questionnaires. Therefore, the IPAQ questionnaires have comparable reliability for the self, telephone and interviewer administered versions, which has important implications for developing countries where access to telephones and literacy levels are lower. The questionnaires were developed for epidemiological studies assessing population levels of PA across countries [47], and thus the sensitivity to change has not yet been investigated.

The long and short IPAQ's were compared to CSA monitor data as a measure of criterion validity (Table 1.3). The long IPAQ had a slightly higher pooled correlation coefficient (r=0.33, 95% CI: 0.26-0.39) compared to the short IPAQ (r=0.30, 95% CI: 0.23-0.36). The association between reported PA and the CSA was similar when the intensity of walking and cycling activities was accounted for and when they were excluded. Therefore, the questions relating to the pace of these activities will be excluded from future versions of the IPAQ questionnaires. Overall, participants better received the short IPAQ than the long IPAQ, as they found the long IPAQ "boring and repetitive" [47]. Because the IPAQ is a relatively new questionnaire, there are few studies investigating its reliability and validity in older adults.

Furthermore, the concurrent validity of these questionnaires with others that have been developed specifically for older adults, warrants further investigation.

1.4.1.7. Lifetime Total Physical Activity Questionnaire (LTTPA)

The LTTPA questionnaire was designed to be interviewer-administered, as opposed to self administered, by fieldworkers trained in cognitive interviewing methods [32]. Lifetime household, occupational and exercise/sports activity is quantified in this questionnaire after subjects report the duration (years) and frequency (months/year, days/week and time/day) of PA for each of these domains. In addition, each reported activity is assigned an intensity level, ranging from sedentary for those activities requiring sitting with minimal walking to heavy for vigorous activities that result in increased heart rate and sweating. Only activities performed at least 10 times during the lifetime were recorded. Total PA was calculated as the sum of occupational, household and exercise / sports activities and recorded as both hours per week and also METhrs/week. Reported activity for each domain (occupation, household and exercise / sport) was calculated for four age epochs, <17 years, 18 – 34 years, 35-49 years and >50 years. The year prior to the interview served as the reference year [32]. Four trained fieldworkers interviewed 30 women, each on two occasions, separated by 6-8 weeks to evaluate the reliability of the LTPA questionnaire [32]. The reliability of total lifetime activity was r=0.74, while occupational activity was more accurately recalled (r=0.87) and exercise / sports activity less accurately recalled (r=0.72) [32].

In summary, while there are numerous questionnaires measuring PA, there are relatively few that have been validated on the older adult population. It is important to find the appropriate tool to measure PA in this population, since the benefits of PA on health and function have been well documented [48-52]. The choice of instrument to measure PA may influence the interpretation of the relationship between PA and health and functional benefits. Thus, it would stand to reason that when measuring PA in older adults, one should use questionnaires that have been validated in this population. Furthermore, the ability to compare PA levels of older adults from different countries, using an instrument like the YPAS or IPAQ, may provide insight into the association between the burden of disease and PA across the globe. Moreover, if the same questionnaire, for example the IPAQ, was used to determine PA in younger and older adults, it could provide insight into the tracking of this behavior across the lifespan.

1.4.2. Factors affecting reliability of Physical Activity Questionnaires in older adults

The reliability of various PA questionnaires is largely affected by the participants' ability to accurately recall the type, frequency, intensity and duration of activities [41]. The intensity of activities appears to be the least reliability reported, may in part, be related to the individual's perception of the intensity of a particular activity. The older or less fit individual may perform an activity at a higher relative intensity than the younger and fitter individual. For example, in a recent study involving 98 well educated, and mostly Caucasian men and women, (mean age 46.2 ± 15.4 years), [53], participants reported activities that were associated with an increase breathing and heart rate as "vigorous" in an interviewer-administered questionnaire, even though these activities were listed as "moderate" in an activity log. These authors suggested that older and less fit individuals might have been more likely to misclassify the intensity of activities, which may be in part related to the relative versus absolute intensity of these activities.

Repeatability studies have shown that older adults are able to recall higher intensity activities (such as those related to exercise, versus those related to recreation) more accurately than the more frequently performed lower intensity activities [19;32;42;54]. The ability to recall exercise-related activities may be easier since they are more structured and may be part of a weekly schedule [19] and are therefore more distinct and memorable.

Subjects participating in repeatability studies may be sensitized to the questionnaire on the second administration and pay more attention to their answers [19]. This is supported by Wolf et al. who demonstrated that there should sufficient time between the administration of different questionnaires to reduce bias [35]. Furthermore, the sample used for repeatability studies may have inherent bias, as subjects are often not randomly selected and this may result in higher repeatability results due to their homogeneity [55]. The repeatability results of a questionnaire may be further inflated if a large proportion of the participants report little or no participation in certain activities at both the test and re-test measurements [55].

Therefore, Booth et al. investigated whether excluding those who reported zero activity on both the test and re-test measures influenced reliability, in a randomly selected population sample of Australians aged 18 years and older [55]. The intra-class correlation coefficients (ICC) for test-retest reliability in participants reporting zero activity were consistently lower for vigorous, moderate and walking activity compared to the total sample [55]. Total energy expenditure, walking and vigorous intensity activities were all in the excellent range for reliability (ICC = 0.86, 0.89, and 0.90 for the total sample respectively, and 0.84, 0.82 and

0.84 for the non zero sample), while moderate intensity activity was less repeatable (ICC = 0.77 for the total sample and 0.64 for the non zero sample) [55]. These results suggest that the total sample, as well as the non-zero sample (excluding those who report no activity at one of the two test administrations) should be taken into account when determining questionnaire reliability [55].

Although one may assume that older age will decrease reliability, it has been found that older adults have better long term memory than short term memory [41] which has implications when assessing lifetime versus current levels of activity. However, the reliability decreases with an increase in length between the two administrations of the questionnaire [41]. Friedenreich et al. reported a similar finding where the correlations between the test and retest for lifetime activity were higher than that for the reference year (r=0.74 and r=0.50, respectively), which measured current activity [32]. These researchers suggested that lifetime memory is more reliable than episodic memory that is used when reporting a specific time period such as the reference year.

In addition to the accuracy of a participant's memory, seasonal and temporal variation in activity patterns will affect the reliability of questionnaires [41]. Occupational activities have been shown to have better reliability than household or leisure related PA [32]. This is probably due the fact that they are performed more regularly, are a repetitive in nature, thus making them easier to recall than those that are performed less frequently or sporadically [32].

The normal variation in activity needs to be considered when assessing reliability as the time elapsed between the test and re-test measures may have resulted in actual change in PA patterns [55]. Thus, if activity levels change between the two administrations, the questionnaire may appear to have low reliability. Booth et al. investigated the influence of usual variations on physical activity patterns influences repeatability results [55]. The repeatability of recall for different time periods was in the fair to good range with walking having the highest ICC (0.74; 95% CI 0.65-0.81) [55]. The repeatability of the questionnaire over the same time period was higher, suggesting that the reliability of a questionnaire assessing PA for the previous 14 days was very good. However, the amount of PA may vary over the two-week period [55]. The effect of weekly variation in physical activity among older adults on questionnaire reliability, may need to be further investigated, particularly among those from developing countries.

1.4.3. Factors associated with measuring validity of physical activity in older adults

Tools that have been used to determine the validity of PA questionnaires include PA diaries, motion sensors and accelerometers and physiological measures such as VO_2 max and body composition. Concurrent validity is determined when comparing the reported energy expenditure or PA behavior from two or more different questionnaires.

1.4.3.1. Concurrent validity

Young et al. compared the PAR and the YPAS in a group of older men and women [34]. These authors found that daily energy expenditure, as well as, participation in moderate PA reported in the PAR were significantly associated with weekly energy expenditure measured in kcal per week ($r=0.37$; $p=0.004$ and $r=0.29$; $p=0.02$), total time ($r=0.3$; $p=0.02$ and $r=0.39$; $p=0.002$), vigorous activity ($r=0.45$; $p<0.0001$ and $r=0.51$; $p<0.001$) and summary index ($r=0.33$; $p=0.01$ and $r=0.39$; $p=0.0002$) measured by the YPAS questionnaire. The YPAS vigorous activity index had stronger associations with the PAR measures ($r= -0.43$ to $r=0.51$; $p<0.01$), while no significant associations were found between light intensity activities and the PAR outcomes [34].

Total weekly YPAS energy expenditure had a stronger relationship with daily energy expenditure and moderate PA measured by the PAR among the African American participants, compared to the non African Americans. For the non African American participants, the YPAS summary, moving and standing indices were negatively associated with the PAR scores. Due to the differences in the results obtained for the African American and Caucasian participants, further investigation is warranted to determine the concurrent validity of the YPAS and PAR in various ethnic groups.

The sensitivity of these two questionnaires for tracking changes in PA patterns was also assessed. Young et al. reported that changes in YPAS dimensions after a 12 week PA intervention were associated with changes in moderate PA and daily energy expenditure measured by the PAR, but most of these associations were not significant [34]. However, the moving index (YPAS) was significantly associated with change in total weekly energy expenditure and in time spent in moderate activities, where $r=0.32$; $p=0.03$ and $r=0.40$; $p=0.005$, respectively [34]. Similarly, a change in weekly energy expenditure was related to changes in moderate PA ($r=0.24$; $p=0.05$). Conversely, changes in walking (YPAS) were negatively associated with changes in daily energy expenditure measured by the PAR. The lack of association between the YPAS and PAR may be due to the fact that PAR reflects predominantly moderate, hard and very hard activities, while the YPAS measures predominantly light intensity activities. Furthermore, vigorous activities in the YPAS are comparable to moderate activities in the PAR [34]. For example, brisk walking is defined as vigorous in the YPAS but as moderate in the PAR. Because brisk walking is classified as moderate intensity in most questionnaires, but as vigorous in the YPAS, further investigation is warranted so as to ensure that the intensity of activities are classified appropriately. For example, brisk walking might be correctly classified as moderate intensity for younger populations, but as vigorous for older populations since the relative intensity would be greater for the older adult. Thus, the definition of activities may vary and is an important consideration when comparing questionnaires.

The YPAS, CHAMPs and PASE questionnaires were administered to both community dwelling and retirement home-based older adults (mean age 75 years) by Harada et al. [42]. Older adults who lived in the retirement homes were six years older and significantly less active than the community dwelling participants. However, the YPAS yielded greater weekly energy expenditure for older adults who lived in retirement homes and also those who were community dwelling, when compared to the results obtained from the CHAMPs and PASE questionnaires [42]. Reported activity for the YPAS and CHAMPS questionnaires had stronger associations with activity monitored by a Mini-logger Series 2000 monitor that was worn for seven days at the waist, compared to that worn at the ankle. In addition, stronger correlations were found for those living at retirement homes, men and those aged 65-74 years. The stronger relationships could be explained the fact that men and younger (< 75 years) individuals participated in higher intensity activities more often, allowing for more accurate recall. For criterion validity, energy expenditure calculated for PA using all three questionnaires (CHAMPs, YPAS and PASE) was significantly associated with lower body function scores (r = 0.46, 0.49 and 0.57, respectively) and the 6-minute walk (r = 0.46, 0.58, and 0.68, respectively). The CHAMPs questionnaire had stronger correlation coefficients with self-reported physical function, general and mental health and pain indices than either the YPAS or PASE.

Harada et al. [42] do not recommend the use of one questionnaire over the others as they have comparable reliability and validity. However, the intra-class correlations between the YPAS and CHAMPs were stronger than that for the PASE and CHAMPs for total (< and > 3 METS) and moderate and vigorous activities. This suggests that since the YPAS and CHAMPs are comparable that either one of the two questionnaires be used where physical activity in household, occupation and leisure time is quantified. However, unlike the YPAS, the CHAMPS questionnaire was sensitive to changes in physical activity after an intervention, suggesting that these two instruments may not be comparable when the aim of the investigation in the evaluation of intervention outcomes.

1.4.3.2. Tools to measure criterion validity

Criterion validity has been measured extensively in younger adult populations. Self-reported PA has been compared to DLW [43], which is regarded as the gold standard, and also to accelerometers [54;56-62], indirect calorimetry [57;60] heart rate monitors [63], and pedometers [56;61;64;65]. However, there are fewer studies investigating criterion validity for PA measurement among older adults.

Starling et al. investigated the accuracy of several measures of energy expenditure in older adults [43]. One of the aims of their investigation was to compare the accuracy of the YPAS and MLTPAQ against the Caltrac motion sensor, used in conjunction with the DLW technique in a group of men and women 45 to 84 years old. The YPAS and MLTPA questionnaires were administered after an overnight stay; during which time the participants received the DLW. The participants wore the Caltrac accelerometer for nine days, and provided a final urine sample 10 days after the first visit. Since the Caltrac accelerometer quantifies energy expenditure in kcal/day, the reported PA from the two questionnaires was quantified as kcal/day for data analyses. For both the older men and women participating in the study, the Caltrac accelerometer and MLTPAQ resulted in lower energy expenditure estimates compared to the DLW and the YPAS. This underestimation by the Caltrac accelerometer led the authors to suggest that it may not be the instrument of choice when quantifying energy expenditure in older adults [43]. Conversely, there was no significant difference between DLW and YPAS energy expenditure for the men (1211 ± 429 kcal/day and 1107 ± 621 kcal/day, respectively) and the women (873 ± 244 kcal/day and 863 ± 447 kcal/day). However, the YPAS had wide limits of agreement from Altman Bland analyses. The authors proposed that its use as a measure of PA energy expenditure may be limited in groups of older men and women based on the wide limits of agreement and also the large variance in the reported PA obtained, as the standard deviation was more than 50% of the mean energy expenditure [43].

The use of accelerometers as a measure of criterion validity is dependent on a number of factors including: compliance with wearing the monitor, accurate reporting of the number of hours that the monitor was worn, and the participant maintaining habitual level of activity during data collection [54]. Accelerometers are an objective measure of energy expenditure when compared to self-reporting in questionnaires, and due to their small size, can be easily used in the field [56;57]. An advantage of accelerometers over DLW is that they are able to measure the intensity and patterns of PA, compared to DLW, which only measures total energy expenditure [59]. One such accelerometer is the Computer Science Applications (CSA) monitor that measures bodily acceleration in a uni-axial plane of motion. Other benefits of using the accelerometers such as the CSA monitor, include its small size which does not hinder normal movement, its ability to store data continuously for six weeks and also the internal real time clock which allows data to be analysed over time interval as short as one second [58].

Factors that need to be considered when using accelerometers are their inability to capture non- locomotor or upper body movement since they may only capture movement in the vertical plane [43;61;62]. In addition, the accelerometers did not show increased counts, and therefore estimated energy expenditure, for graded treadmill walking. These results imply that accelerometers are unable to reflect the increased energy expenditure of activities that involve increased muscle loading due to isometric contractions, upper body movement and added weight bearing [56]. This may be of special significance to those older adults who walk slowly, and sometimes have little vertical acceleration due to their gait patterns being shuffling in nature.

However, this does not mean that we should discount accelerometers to quantify energy expenditure. The CSA monitor is able to measure the intensity, duration and frequency of physical activities and is a useful tool to measure habitual activity, or PA patterns [61]. Furthermore, these researchers [61] stated that although there are errors in energy expenditure estimation, the accelerometers are able to discriminate between individuals differing in habitual levels of PA. This is supported by Sirard et al. who compared the CSA data to tertiles of activity derived from an activity diary, and found that the monitor classifies individuals "reasonably well" according to their habitual levels of activity (Kappa 0.53; $p<0.00$) [59]. Thus the CSA may be useful for studying activity patterns over time [59]. This is further evidenced by the reported decrease in PA over the weekend (recorded in the diary) corresponding to a decrease in CSA monitor counts. These findings highlight some of the challenges in measuring energy expenditure accurately in daily activities.

The use of accelerometry has been previously investigated in older adults. Focht et al. evaluated the validity of the CSA monitor during a bout of exercise in older men and women (mean age 65 years) with chronic disease [60]. The CSA monitor counts were compared to pedometer counts, estimated METs of the aerobic session, and 6-minute walk performance. The participants exercised at 50-80% of their heart rate reserve for approximately one hour. The activity counts obtained from the CSA monitor during the aerobic component of the exercise session equated to light intensity activity for 28% of the sample while the rest of the participants performed the exercises at a moderate intensity. Correlation analysis revealed significant associations between the CSA monitor and estimated METs ($r=0.60$; $p<0.01$); pedometer counts ($r=0.47$; $p<0.01$) and the 6-minute walk performance ($R=0.62$; $P<0.01$). These researchers also measured the concurrent validity of the CSA monitor with the Cosmed K4 b^2 portable gas analysis unit in 12 participants (mean age 63 years). Pearson product moment correlations revealed a significant association between the CSA monitor and Cosmed K4 b^2 unit ($r=0.72$; $p<0.01$) suggesting good concurrent validity. These authors state that the significant relationships between the CSA monitors and the pedometer, estimated METs, the 6-minute walk and the Cosmed K4 b^2 unit, provides support for the use of this accelerometer to monitor moderate intensity exercise among older adults with chronic diseases. Another important finding was that although the heart rate and Rate of Perceived Exertion (RPE) indicated that participants were exercising at a moderate intensity, the CSA counts were equivalent to that of light intensity for a third of their sample. Thus the intensity classification and cut off points from regression equations described by Freedson et al. [66], may need to be modified for this older population [60].

Ainsworth et al (2000) compared three methods to measure PA, a 21-day PA log, a PA questionnaire and the CSA accelerometer for which regression equations were used to calculate energy expenditure [53]. PA over 21 days was measured in 83 adults (mean age, 47.2 years) using PA logs (3 X 1 week), PA questionnaire (non occupation walking, moderate-and-vigorous intensity recreational activities) and the CSA monitor. Three different regression equations, namely, Hendelman, Freedson and Swartz [56;57;66], were used to calculate daily time spent in moderate and vigorous activities per day.

These equations utilize cut points for various MET values and are based on activity counts obtained from the CSA monitor. The duration of moderate intensity PA was highest using the Hendelman equation [56], and lowest for the Freedson equation [66], while each of the equations indicated that individual's spent less time in hard and very hard activity compared to that recorded in the activity log. The strongest relationship between the CSA scores and the PA was obtained when using the Hendelman equation [56] for both moderate ($r=0.35$) and vigorous ($r=0.36$) activities. The Freedson equation [66] had the weakest relationship between the CSA score and activity log for moderate intensity activity ($r=0.24$; $p<0.05$), while the Swartz equation [57] had the weakest relationship for vigorous intensity activity ($r=0.31$; $p<0.01$).

These differences may be partly attributed to the fact that the Freedson equation [66] was developed using treadmill walking and jogging as a reference, while the Hendelman [56] and Swartz equations [57] were developed from a variety of moderate intensity activities [53]. In addition, the moderate intensity cut point for Freedson was higher than the other two equations, which may be set too high to capture a variety of moderate intensity activities [53]. This equation has been shown to under predict the energy expenditure of activities involving upper body movement and carrying loads, which could contribute to some moderate activities being too low for the Freedson cut points [53]. Therefore, it is important that the equation used is taken into account, when trying to quantify an individual's energy expenditure and also when determining if they are meeting the recommended levels of physical activity. For example, because older adults are more likely to participate in light and moderate intensity activities, the Heldelman [56] and Swartz [57] equations may be better suited to determine energy expenditure.

The concurrent validity of the CSA monitor has been investigated by comparing it to other accelerometers and motion sensors. Basset et al. compared the validity of four motion sensors, three accelerometers and an electric pedometer (Yamax SW-701), during moderate intensity PA in a field and laboratory setting [61]. The three accelerometers used were the Caltrac, the Kenz Select 2 that stores data in one-day epochs and the CSA accelerometer, which can store data continuously for 22 days. Eighty one participants aged 19-74 years performed various activities depicting yard work, housework, family care, occupation, conditioning (stretching, slow and brisk track walking) and recreational activities for 15 minutes while wearing the accelerometers and pedometers. Oxygen consumption was measured simultaneously using a portable indirect calorimetry system (Cosmed $K4b^2$). Data obtained from the CSA monitor were used to calculate estimates of energy expenditure from three different regression equations. Gross energy expenditure was calculated from equations designed by Hendleman [56] and Freedson [53] while net energy expenditure was calculated using the equation from the CSA manual [61]. The correlations between the three accelerometers and the pedometer were high suggesting that the motion sensors all measure vertical accelerations of the body in a similar manner.

In summary, PA questionnaires, together with accelerometry are used broadly to explore the association between habitual or increased levels of PA and morbidity and mortality. Questionnaire based assessments are often the most cost effective and practical method for measuring PA in epidemiological surveys. The choice of instrument will, in part be based on previously reported reliability and validity, and also the envisaged outcome of the research study.

1.5. Physical Activity and health in older adults

1.5.1. Brief overview of physical activity and all cause and coronary artery disease (CAD) mortality in older adults

1.5.1.1. Longitudinal Studies

As previously described in section (1.1.3), PA has been associated with reduced mortality from chronic diseases [49;67-70]. Landi and colleagues investigated the relationship between moderate intensity PA and all cause mortality in older adults with moderate to severe impairments in ADL [67]. The participants in the study were Caucasian and mostly women, for which the mean age was 78.2 ± 9.5 years. A single question inquiring about the average number of hours spent per week in household, gardening, recreational and light exercise was used to obtain information on PA behavior. Only 25% of the sample older than 70 years and 21% of those between the ages of 70 and 80 years participated in two or more hours of PA per week. The physically active older adults had a 50% reduced risk of all cause mortality compared to their sedentary counterparts (RR=0.51; 95% CI: 0.35-0.73) [67]. The risk reduction due to increased PA was present even after adjusting for confounders such as age, comorbidity as well as physical and cognitive disability.

Encouraging older adults to increase or maintain their current levels of PA may result in improvements in both health and functional performance. Consequently, one of the outcomes of the Longitudinal Aging Study Amsterdam was to determine if a change in PA was related to a change in mobility performance [52]. This cohort comprised of a representative sample of men and women between the ages of 55 and 85 years (n=2109) who were followed up after three years [52]. Visser and co workers quantified PA using an interviewer-administered questionnaire developed by Voorips et al [71] and Caspersen et al. [72]. In addition, 6m timed walk and sit to stand test (time taken to complete 5 repetitions) performance was evaluated [52]. Participants were assigned a score ranging from zero (unable to complete the test) to four (fastest quartile) for both tests. These scores were summed to create a mobility performance score, which ranged from zero to eight. The men and women participating in sports activities experienced a smaller decrease in mobility than those who did not. Even the participants who were sedentary at baseline and adopted sports behavior during the three years, experienced smaller reductions in mobility than those who remained inactive. Similarly, total PA, expressed as hrs/ day and kcal/day, was significantly related to change in mobility status, where those who were most active had the least decreases in mobility than those who were least active. This relationship remained significant when considering lower intensity activities such as walking and household activities, which are commonly performed in the elderly. For those who are inactive, and not able to participate in a specific sport, PA intervention programs could provide a means to change their sedentary behavior.

In addition, the risk factors associated with all cause and CAD mortality were investigated by Panagiotakos et al. [68]. Their participants comprised of the Corfu cohort, which was part of the Seven Countries Study. The study population was 529 men who were 40-59 years old at baseline, of which 68 were still alive at follow up forty years later. PA, together with age, diastolic blood pressure, smoking, forced expiratory volume and skinfold thickness were associated with all cause mortality [68]. However, only age, smoking and BMI were associated with CAD mortality [68]. PA plays a role in reducing or maintaining BMI values within the acceptable ranges, and may therefore indirectly affect CAD mortality.

Indeed, a sedentary lifestyle has previously been identified as an independent risk factor for CAD [73]. The relationship between PA and mortality was investigated in the Jerusalem-70-Year-Olds Longitudinal Study, which comprised of men and women older than 70 years [49]. The prevalence of hypertension, diabetes and ischemic heart disease (IHD) among both the men and women in this cohort study was lowest for those who were most active, compared to those who walked less than 4 hours per week [49]. Furthermore, PA has previously been shown to reduce total triglycerides, cholesterol, BMI and systolic and diastolic blood pressure [73].

Therefore becoming physically active may well attenuate the health risks associated with a sedentary lifestyle. In the Study of Osteoporotic Fractures (SOF), the older Caucasian women participating in this cohort were divided in to four groups, those who were physically active at baseline and follow up, those who were sedentary at baseline and follow up, those who were active at baseline and became sedentary, and those who were sedentary and become physically active [69]. Those who were most active at baseline had the lowest all cause and cardiovascular disease mortality rates than those who were least active, hazards ratio 0.68 (95% CI: 0.59-0.78) and 0.58 (95% CI: 0.46-0.74), respectively [69]. Moreover, the women who were sedentary at baseline and became PA during the 5.7 years had reduced risk of all cause mortality (HR: 0.52, 95% CI; 0.40-0.69) compared to those who remained sedentary. These results support the adoption of a PA lifestyle, even in those who are older than 65 years and previously sedentary, as health benefits were associated with increased levels of PA [69].

The relationship between miles walked per day and CAD morbidity and mortality was explored among those who were part of the Honolulu Heart Program [74]. The men, who reported their daily walking in distance in 1991 to 1993, were followed up two to fours years later. Nearly a third of the men walked less than a quarter mile per day, 40% walked 0.25-1.5 miles per day and the remaining 30% walked more than 1.5 miles per day. The risk for CAD was significantly reduced among those walking more than 1.5 miles per day. In fact, the incidence of CAD among these men was half of that for those who walked less than 0.25 miles per day (2.5 versus 5.1%). Furthermore, a dose response was present as the risk of CAD was reduced by 15% for every 0.5mile increase in daily distance walked [74]. Walking is one of the most commonly reported PA among older adults, and thus encouraging older adults to increase the daily walking distance may result in significant health benefits.

Therefore, regular PA plays a role in decreasing the risk of all cause mortality and also in the prevention and management of chronic conditions such as diabetes, heart disease, hypertension and osteoporosis [67]. It is not within the scope of this literature review to comprehensively evaluate the evidence for the role of PA in ameliorating all chronic-disease specific conditions in older adults. However, as three of the experimental chapters were directed at describing the relationships between PA in older adults and bone mineral density, as well as blood pressure control and frailty, these topics will be elaborated in more detail.

Hypertension increases in prevalence with age and has been previously identified as an independent risk factor for coronary artery disease [73]. Moreover, in South Africa, the prevalence of hypertension is high in the Mixed Racial Ancestry and Black population groups, which underscores the importance of effective management of this condition [20]. Osteoporosis on the other hand, has not been widely diagnosed in these populations, largely due to a lack of resources available for screening and BMD measurement.

1.5.2. Hypertension

Most older adults are insufficiently active and have at least one chronic condition [69]. Indeed, among Black South Africans and those of Mixed Racial Ancestry (Coloured) older than 60 years, and residing in the Cape Peninsula, the prevalence of hypertension has been reported to be as high as 48.7% and 76.5% for women and 25.7% and 66.7% for men, respectively [75;76]. Furthermore, only half of these individuals reported taking hypertension medication, and of these, only 21.7% had controlled blood pressure (<160/95). Similarly, the prevalence of hypertension is higher among African Americans [77;78] and subsequently they experienced a higher rate of fatal stroke, heart disease deaths and end stage renal disease [77] than their Caucasian counterparts. Therefore, the high prevalence of hypertension and the poor control thereof, indicates that these "at risk" populations may benefit from intervention programs to assist with the treatment of this condition.

In American populations studied, the prevalence of hypertension is lower among those individuals who are physically active [49;77], including older adults [79]. Bassett et al. investigated the relationship between leisure time PA (LTPA), ethnicity and hypertension in US adults aged 18 years and older [77]. The study population comprised of non-Hispanic Blacks (n=4 244), Mexican Americans (n= 4 219) and non-Hispanic Caucasians (n=6 436) without hypertension disease states that may have restricted habitual PA levels. The participants reported the frequency with which they performed LTPA such as jogging, running, cycling, swimming, dancing, calisthenics, yard work and weight lifting, in the previous month. In addition, the number of times they walked one mile or more, without stopping, during the previous month was recorded. The non-Hispanic Blacks reported the least amount of LTPA, followed by the Mexican Americans. The Caucasian sample was more likely to report participation in moderate to vigorous PA, at least five times per week [77]. Consequently, the prevalence of hypertension was highest among the non-Hispanic Blacks and second highest for the Mexican Americans [77]. Furthermore, the prevalence of hypertension remained highest in the non-Hispanic Blacks, even after controlling for reported levels of LTPA. As a result, the authors of this study concluded that ethnicity (particularly non-Hispanic Black), may be an independent risk factor for hypertension. For each of the populations studied, the prevalence of hypertension was lower among the more active groups, however this relationship only reached significance for the Caucasian population [77]. Thus there appears to be a beneficial effect of LTPA on blood pressure, however the effect varies between different ethnic groups.

The relationship between both current and lifetime PA with blood pressure was investigated by Charlton et al [20] in older South African men and women from the Mixed Racial Ancestry group. Current PA was measured using the YPAS questionnaire [19], and lifetime PA was measured using a questionnaire adapted from Kriska et al [80;81]. The lifetime PA questionnaire included household, occupational and leisure time energy expenditure for five age epochs (14-21 years; 22-34 years; 35-49 year; 50-64 years and ≥65 years). One of the most interesting findings of Charlton and co workers was that lifetime (sum of all the age epochs) moderate intensity energy expenditure related to occupational activity was significantly associated with systolic blood pressure (r=-.024; $p<0.05$) [20]. In addition, total (household + occupational + leisure time PA) moderate intensity PA during the age periods 22-34 years and 35-49 years, was significantly and inversely associated with systolic blood pressure, r=-0.22 and r=-0.22, respectively. Conversely current PA was not associated with blood pressure. A possible explanation for the lack of association between current PA and blood pressure was the low levels of PA reported by this sample [20]. Furthermore, the ages during which PA was related to blood pressure largely represents the occupationally active period. Since these older adults participated in mostly manual labor occupations, this domain may have accounted for a large proportion of moderate intensity activities, resulting in a positive association with systolic blood pressure. These findings highlight the importance of measuring lifetime or historical physical activity levels, in studies that are investigating the potential benefits of PA for reducing the risk of chronic diseases such as hypertension.

1.5.2.2. Intervention Studies

In order to determine the effects of regular PA on blood pressure, Young et al. compared the effects of a 12-week moderate intensity aerobic intervention with Tai Chi exercises in previously sedentary older adults [82]. Both the aerobic training and Tai Chi exercise were conducted in a supervised environment twice per week for one hour. In addition, home-based exercises were prescribed so that the older adults were exercising four to five days per week. Even though the aerobic training group had higher levels of energy expenditure and spent more time in moderate PA at baseline, both exercise interventions resulted in similar improvements in blood pressure control [82]. Blood pressure decreased significantly after only six weeks and further improvements occurred between six and 12 weeks [82]. However, the improvement observed after the first six weeks was greater than that observed for the second six weeks of the trial [82]. Thus Young and coworker's findings suggest that both light and moderate intensity exercise results in improvements blood pressure, and these improvements are evident after a relatively short time period (6 weeks). Further investigation is therefore required to determine in other types of low intensity exercise have similar effects on blood pressure as Tai Chi training.

Santa-Clara and coworkers explored the blood pressure response to a six-month intervention trial in African Americans and Caucasian postmenopausal women who were not hypertensive [78]. The participants in the exercise group trained three to four times per week and exercised for 45 to 60 minutes per session. The intervention included treadmill walking or jogging, stationary cycling and rowing which was prescribed at 70-85% of maximal heart rate. Resting diastolic blood pressure was reduced for the African Americans but not for the Caucasian women, although both groups did not experience any changes in systolic blood pressure [78]. A possible explanation for the exercise being more beneficial for the African American women was that they had higher baseline diastolic values than the Caucasian women.

Similarly Motoyama et al. investigated the effectiveness of a longer (9 months) low intensity exercise intervention program in elderly hypertensive patients [83]. In contrast to the group studied by Young et al [82] and Santa-Clara et al [78] all participants in this study were hypertensive and taking the appropriate medication. The intervention group participated in treadmill exercises for 30 minutes per day, three to six days per week, for nine months, while the control group maintained their usual levels of PA. Systolic blood pressure decreased significantly in the intervention group, from 147 ± 14.1 mmHg to 132.5 ± 11.0 mmHg, over the first three months, after which it stabilized. These improvements were significant when compared to the control group. Furthermore, blood pressure at six and nine months had also improved significantly in the intervention group, when compared to the control group.

An improvement in blood pressure was observed for each of the studies described [78;82;83] even though the duration of the intervention differed. Thus, the length time required before improvements are observed needs to be established. In a meta analysis by Kelley and Kelley [84], the intervention programs included ranged from 16 weeks to 52 weeks, and was 24 weeks in four out of the seven studies investigated. Each of these studies found a small but significant improvement in systolic blood pressure (2%) and a non-significant improvement in diastolic blood pressure (1%) [84]. Therefore, it seems that a minimum of 16 weeks may be a feasible duration for the intervention program, but with testing completed pre, mid and post intervention, as described by Motoyama et al [83] and Young et al [82].

While the previous three studies [78;82;83] investigated the effects of aerobic training on blood pressure, Martel et al. investigated the effectiveness of a strength training intervention program in older adults [85]. The men (n=11) and women (n=10) participating in this study completed the six-month strength-training program, exercising three times per week. The strength-training program comprised of nine exercises, for which two sets of 15 repetitions were performed for the lower body exercises and one set of 15 repetitions for the upper body exercises [85]. Systolic and diastolic blood pressure decreased significantly after the six month intervention program, 131± 2 to 126 ± 2 mmHg and 79 ± 2 to 75 ± 1 mmHg, respectively, $p<0.01$, when the men and women were combined. However, systolic blood pressure decreased significantly only for the men when analyzed separately to the women. Conversely, diastolic blood pressure was significantly reduced in both men and women [85]. Thus strength training may have potential benefits on blood pressure, however, the benefits were not consistent for men and women. Furthermore, this study did not include a control group and the sample size was relatively small, thereby warranting further investigation.

Subsequently, Kelley and Kelley conducted a Meta analysis to explore the effectiveness of resistance training intervention program on systolic and diastolic blood pressure [86]. Eleven studies were included, reflecting 14 exercise and 12 control groups. The duration of these studies ranged from six weeks to 30 weeks, and the frequency of exercise sessions ranged from two to five times per week. The mean decrease in systolic blood pressure was –3±3 mmHg and –3±2mmHg for diastolic blood pressure across all of the studies [86]. Therefore, resistance training appears to be beneficial for blood pressure in the older adult population. However, Kelley and Kelley's review underscores the need for additional studies that include hypertensive patients and also non-Caucasian populations.

In summary, the potential blood pressure lowering effect of moderate and light intensity exercise could assist in the management of hypertensive patients. This would be of particular benefit to developing countries such as South Africa, where the demand for health care services exceeds the current available resources [87]. However the effectiveness of an exercise intervention program has not been previously investigated in older adults from previously disadvantaged populations, or in communities undergoing epidemiological transition, who may be at increased risk for hypertension.

1.5.3. Osteoporosis

In addition to hypertension, PA has also been associated with increased bone mineral density (BMD), as it plays a role in increasing peak bone mass and reducing the rate of bone loss that occurs with aging. This section of the literature review will focus on the role PA plays in attenuating bone loss in older adults.

Osteoporosis has been defined as a systemic skeletal disease in which bone strength is compromised due to low bone mineral density (BMD) and quality, resulting in an increased risk of fracture [88]. The WHO defined osteoporosis as BMD (g/m^2) less than 2.5 SD below the average peak bone mass in young adults [89]. BMD is a component of bone strength and serves as a diagnostic tool for osteoporosis, particularly where patient history and clinical findings point towards osteoporosis [89]. Further, BMD is an important and quantifiable risk factor for fractures [88] and is therefore an important parameter in the older adult population.

1.5.3.1. Physical Activity in older adults, bone density and bone quantitative ultrasound measures (QUS) measures

It is important to note that the risk for fracture is multi dimensional and is not solely based on BMD results [89]. In addition, BMD is influenced by a number of factors such as PA, calcium intake and absorption, smoking and alcohol and caffeine intake. This section of the review will focus on the role of PA, both current and lifetime on bone mass in older adults.

Habitual PA has been identified as one of the risk factors for low quantitative ultrasound (QUS) values [90] and regular weight-bearing activities such as walking is known to increase BMD [91;92]. Further, muscle contraction associated with PA places a mechanical strain on the bone, resulting in bone remodeling and increased BMD [92]. Thus the decrease in BMD that occurs with aging may be due, in part, to an age related decrease in habitual physical activity levels. Moreover, there is some evidence that increased levels of lifetime PA may be protective.

1.5.3.2. Bone mass measurement in adults

The purpose of measuring bone mass is to assist the clinician with the diagnosis of low bone mass and osteoporosis, fracture prediction and for ongoing monitoring [93]. Despite the high cost of densitometry, dual x-ray absorptiometry (DXA) is regarded as the gold standard for measuring BMD [89;93;94]. In addition, the DXA is able to measure bone density at the spine and femoral neck, which are the sites at which most fractures occur [95].

More recently, bone quantitative ultrasound measures (QUS) of the calcaneus have been identified as an option for screening for osteoporosis, particularly where there is limited accessibility to DXA equipment [96]. This is especially helpful in developing countries that are typically under resourced, as QUS is less expensive than densitometry and can be used in the field [93;94]. The QUS measurement is taken at the calcaneus, which is mainly trabecular bone, and has similar rates of bone loss to the spine [97]. Measurements obtained from QUS are broadband ultrasound attenuation (BUA), speed of sound (SOS) and stiffness (SI) [93]. An important consideration when using ultrasound is that calcaneal measurement may not sufficiently predict a bone mineral density, measured from another skeletal site such as the spine [97]. However, it can serve as a proxy measure for hip fracture determination, since it has similar diagnostic sensitivity to the DXA measurements of the femur [97].

QUS has been found to predict fracture risk independent of BMD [93;98] with odds ratios similar in magnitude to that obtained from densitometry [93]. For inter trochanteric fractures, femoral neck BMD and BUA had similar relative risks, RR=3.9 and 3.3, respectively, in a group of women participating in the Study of Osteoporotic fractures (SOF) longitudinal study [94]. In addition, for every standard deviation reduction, the risk of hip fractures was doubled amongst these women aged 65 years and older (RR 2.0; 95% CI: 1.5-2.7) [90;94]. A separate study in 64 Caucasian women found stronger correlations between BUA and BMD, r=0.73 [93]. Therefore, these researchers have shown that BUA is able to predict fractures and the association with fracture risk was similar to that of BMD measured by DXA [94].

1.5.3.2. Current physical activity

Similar to BMD, muscle mass declines with age, where 10% is lost from 25 to 50 years, after which the rate of muscle loss increases resulting in an approximate 40% decline over the lifetime [99]. Proctor et al. used the DXA to measure BMD and bone mineral content (BMC) at the lumbar spine, femur and wrist, in addition to total body bone mineral mass and lean body mass [92]. The participants of this study comprised of 348 men (mean age 55.4 ± 19.6 years), 138 pre menopausal (mean age 35.0 ± 18.6 years) and 213 postmenopausal women (mean age 67.8 ± 13.2 years). Habitual PA for the previous 12 months was assessed to determine the type, duration, frequency and intensity of activities. Lower body strength was measured qualitatively with individuals reporting scores ranging from "1" for normal function, to "3:" for severely impaired, while handgrip strength was measured using a dynamometer. For both the men and women, total body bone mineral mass (TBBM), lean body mass (LBM) and physical activity decreased with increasing age [92]. TBBM was similarly associated with

LBM in the men (r=0.77) and the women (r=0.74) [92]. Similarly, total skeletal muscle mass was significantly associated with TBBM in the men (r=0.64) and women (r=0.54) [92].

Results from a multivariate analysis, which included skeletal muscle mass, height, PA, hand grip strength and age, revealed that light intensity PA during the past year was positively related to TBBM for both men and women (light PA β=0.02; p<0.001). This is of importance to the older adult, since they are more likely to perform lower intensity activities than moderate or high intensity. However, after adjusting for muscle mass, TBBM was not independently associated with PA [92]. Although Proctor and co workers [92] found an association between BMD and past year PA, this relationship was not independent of PA changes in lean body mass.

Lean body mass is related to body size [92] and smaller body size and weight has in turn, been associated with increased risk of hip, pelvis and rib fractures in older adults [100]. Saadi and coworkers investigated the relationship between anthropometric and lifestyle factors on QUS parameters in a population based sample of Arabian women, aged 20 years and older [101]. In addition to body mass index (BMI) and body fat percentage, current PA for the previous six weeks was assessed. The QUS results for the post-menopausal women (mean age 59.9 ± 9.7) in this sample were significantly associated with weight (r=0.39; p<0.01), BMI (0.43; p<0.01), and lean body mass (r=0.40; p<0.01) and PA (r=0.42; p<0.01). In the multivariate analysis, BMI and PA remained significant predictors of BUA (r=0.59; p), SOS (r=0.62; p), and QUI (r=0.66) together with age [101].

Blanchet and colleagues had comparable findings among Caucasian post-menopausal women (n=1162, mean age 57.8 ± 7.2 years) [102]. The sedentary post-menopausal women participating in this trial had lower BUA, SOS and SI and femoral neck BMD scores than the moderately and very active women. Furthermore, leisure time PA was significantly and independently associated with both QUS measures and femoral neck BMD [102]. However, there was no association between PA and lumbar spine BMD [102]. In the multivariate analysis, current participation PA more than twice per week, was an independent predictor of SOS and SI values. Both these studies [101;102] highlight the importance of current PA for postmenopausal woman.

Furthermore, Gregg et al. investigated the relationship of lifestyle factors, including PA on QUS measurement in 393 women aged 45-53 years [90]. Most of the women were Caucasian (92%), although there was a small sample of African Americans (7%) and other races (1%). The participants reported lifetime physical and current PA in two questionnaires, the lifetime PA questionnaire developed by Kriska et al. [80] and the MLTPAQ. Habitual activity for three age epochs, 14-21 years, 22-34 years and 35 years to present age was reported. In addition to QUS, BMD was measured at the hip and lumbar spine using DXA.

Current PA participation (past year) was significantly associated with higher SOS and BUA measures, where each 1000kcal of leisure time PA was associated with a 1.9dB/MHz increase in SOS score and 1.0 m/s increase in BUA [90]. In the multivariate analysis that included age, lean mass, BMI, smoking, PA, dietary calcium, vitamin D supplements and hormone replacement therapy (HRT), past year PA was still related to SOS measures. Likewise, past year PA and PA from age 35 years were significantly associated with femoral neck BMD. This association, however, was not evident with spinal BMD, which supports Blanchet et al's findings [102]. After controlling for other factors in the multivariate analysis, past year PA was still associated with femoral neck BMD. These results, together with that of Blanchet and colleagues, suggest that recent activity is an important predictor of QUS and femoral neck BMD [90]. Furthermore, these researchers [90] found that the magnitude of the associations between PA and QUS measures mirrored that of physical activity and BMD.

The mode of activity appears to impact on BMD. For example, Brahm et al. found that runners had higher BMD for sites directly loaded with running, compared to the control group, for total body bone mass (3.6% higher), legs (9.6% higher), femoral neck (10.0% higher), trochanter (9.9% higher), and Ward's triangle (11.8%) [91]. Similarly, BUA and SOS were higher for the runners compared to the controls (9.2 and 3.1%, respectively) [91]. However, older adults are less likely to participate in running, and more likely to participate in lower intensity activities such as walking.

Although walking is associated with less impact loading than running, Ebrahim et al. investigated the effects of brisk walking on BMD in postmenopausal women (mean age 66.4 ± 7.8 years) who had suffered an upper arm fracture during the two years preceding the trial [103]. The women participating in this placebo control trial were randomly assigned to either an intervention group which comprised of brisk walking, or the placebo group who performed upper body exercises. Ebrahim and colleagues found that the women who participated in brisk walking for at least 40 minutes, three times per week, experienced lower rates of femoral neck bone loss compared to those who performed only upper body exercises [103]. However, both groups of women (brisk walking and upper body exercise / placebo group) experienced small increases in lumbar bone mineral density after two years [103]. Surprisingly, the brisk walking group experienced more falls than the placebo group during the first year of the intervention [103]. The higher incidence of falling may be related to increased exposure to external factors while walking, for example, uneven pavements. After two years the number of falls reported were similar for the brisk walking and upper body exercise groups, although the cumulative risk for falls remained higher in the walking group [103]. Despite the increased risk of falling amongst the walkers, the risk of fracture was lowest in this group [104].

Therefore current PA, such as walking, loads the bone and plays a role in maintaining or improving BMD and reduces the risk of fracture. However, the maintenance or increase in bone mass associated with walking is lost if the individual stops exercising [104;105]. Conversely, women who were previously sedentary and started walking, showed a significant increased in calcaneal BUA, compared to women who remained sedentary or stopped walking [104]. The participants, who walked 3 times per week for 2 years, did not increase their bone mass further after one year. In fact, these participants experienced a reduction in femoral neck and calcaneus BMD, as well as calcaneal BUA. This reduction was attributed to a decreased in walking speed which may not have sufficiently loaded the bone to further enhance bone mass [104].

The impact loading of specific physical activities on bone was further investigated by Jakes et al. in men and women between the ages of 45 and 74 years who were participating in the European Prospective Investigation into cancer (EPIC) cohort [106]. Recreational activities were classified according to the impact loading as low, moderate or high impact. High impact recreational activity was positively associated with QUS measures for both the men and women. This relationship was linear for the men, but for the women the QUS measures were only associated with the presence (versus the absence) of high intensity activities. Low and moderate impact activities were not associated with any of the QUS measures. However, the number of flights of stairs climbed was significantly and positively associated with QUS. Furthermore, the amount of time spent watching television was negatively associated with QUS for the women. While it may not be advisable to prescribe high impact activities to the older adults with osteoporosis [106], these results suggest that limiting sedentary activities such as watching television, and encouraging stair climbing will assist in the maintenance of bone density [106].

Evidence further suggests that PA intervention programs to increase BMD in pre and postmenopausal women should be based on activities that load the bone. Humphries et al. investigated the effectiveness of a 24-week high intensity weight-training program versus a low-intensity walking program in women aged 45-65 years who were either taking or not taking HRT [99]. The study design consisted of four groups, two participating in weight-training (a HRT and non HRT group) and two groups participating in the walking program (a HRT and non HRT group). The four groups showed no significant differences in lumbar spine BMD after the 24-week intervention, although the walking group not taking HRT tended to lose more BMD compared to the other groups [99]. Lack of statistical power and the relatively short duration of the intervention may have accounted for failure to show changes in lumbar spine BMDI in the high intensity weight-training group [99]. However, both the weight-training groups did demonstrate a significant increase in muscle strength. The stress placed on the lumbar spine may have increased due to the improved muscle strength and may have resulted in favorable changes to BMD had the intervention longer than 6 months.

Conversely, Nelson et al. reported an increase in femoral neck and lumbar spine BMD after a one-year high intensity strength training intervention in postmenopausal women [107]. This study differs from Humphries et al. [99] by the length of intervention and the nature of the activities in the control group (walking in Humphries versus no activity in Nelson). Furthermore, in the study by Nelson et al. none of the participants were receiving HRT [107]. These differences may explain, in part, the lack of improvement in BMD for Humphries et al. [99]. In addition to improved BMD, the strength training group experienced preservation of total body bone mineral content, and increased muscle mass, muscle strength and dynamic balance, compared to no improvement in the control group [107].

Therefore current PA has been shown to be associated with BMD, although most of the previous studies comprised largely of Caucasian women. In addition, the measurement of current PA did not always include physical activities that are associated with household chores and yard work, which are commonly performed by older adults, particularly women. As a result, further investigation is warranted where the measurement of current PA is not restricted to only leisure time PA. Furthermore, further research investigating the relationship between current PA and BMD in non-Caucasian populations will allow for comparisons of BMD and PA in different ethnic groupings.

1.5.3.3. Lifetime physical activity

One of the first studies to research the relationship between lifetime PA and bone mass and area, was conducted by Kriska et al. [81]. These researchers measured leisure time PA during four age epochs, 14-21 years, 22-34 years, 35 to 50 years and 50+ years in a group of postmenopausal Caucasian women. Reported PA from each of these epochs was weakly but significantly associated with baseline radial bone measurements. However, only bone area, not density was associated with lifetime PA after co varying for confounders such as age, height, weight and milk consumption. Moreover, when walking was included with lifetime PA, bone area was significantly related to activities performed between the ages of 22 and 34 years [81]. These ages represent time during which bone mass is still accruing [81].

Lifetime and current PA and the type of activities associated with bone density were investigated more recently in a group of well-educated premenopausal women (mean age 41 years, age range 28-50 years) [108]. Activity, that included exercise, occupation and housework, was measured during five age epochs, 6-12 years, 13-19 years, 20-39 years, more than 40 years, and also for the previous two years. In addition, the number of hours spent in weight bearing and non-weight bearing activities was calculated. Total body BMD, as measured by DXA, was significantly associated with lifetime weight bearing exercise (r=0.54) and lifetime total weight bearing physical activity (inclusive of housework and occupational activity) [108]. Peripheral BMD (sum of right and left arm and right and left leg) was also significantly associated with lifetime weight bearing exercise [108]. In addition, these authors found that PA between the ages of 6 and 39 years had a stronger association with premenopausal BMD, than current PA. Therefore this study indicates that total lifetime weight bearing activity, which is inclusive of housework and occupational activity, may be a stronger determinant of current peripheral and total body BMD, than total PA which includes non weight bearing exercise. Weight bearing household and occupational activities had similar associations with BMD as weight bearing exercise in this sample. Consequently it is important to include these activity domains when measuring the effects of lifetime activity on BMD.

Conversely, Gregg et al. did not find a relationship between lifetime PA and QUS measures, since PA measured in the first two age epochs, 14-21 years and 22-34 years was not associated with BUA or SOS [90]. SOS and BUA were, however, associated with PA from 35 years to the participant's present age [90]. The differences between this study and that of Ulrich et al. [108] may be related to BMD measurement technique, since the latter study used DXA. Furthermore, Ulrich et al. did not measure the association between lifetime activity and calcaneal BMD or BUA, which may have yielded different results to that of total body and peripheral BMD [108].

Calcaneal BUA and radial BMD and their association with lifestyle factors, including PA were investigated by Korpelainen and co workers different BMI tertiles in a population-based sample of older Finnish women [109]. These researchers found that older women (mean age: 72 years) in the highest BMI tertile were the least active and also had higher calcaneal BUA and radial BMD scores than the thinner women [109]. The higher BUA and BMD scores were explained by the fact that the body responds to the mechanical stress provided by body weight by stimulating osteoblast activity, which in turn, increased BMD [109]. Recreational PA was not associated with BUA values for the entire sample, however, the women in with the lowest BMI and who were inactive were at the highest risk for reduced calcaneal BUA [109].

Furthermore Korpelainen et al. found an inverse relationship between lifetime occupational activity and calcaneal BUA, particularly for the women in the lowest BMI tertile [109]. The women with sedentary occupations were thought to have higher levels of education, which could have resulted in them having improved nutritional awareness and also having higher recreational PA levels, thereby protecting them against loss of bone mass [109]. When comparing lifetime recreational activity and BUA for the tertiles of BMI, the researchers found that in women with the lowest BMI, recreational activities at ages 30 years, 50 years, and current age, were significantly associated with BUA. No relationship was found between lifetime recreational PA and radial BMD. The lack of association between radial BMD and PA may in part, be due to the fact that it is a non-weight bearing site, and thus is unaffected by the direct loading experienced from physical activity [109].

Occupational and leisure time activities were measured in a Swedish population aged 22 to 84 years to determine their relationship with bone mass and biochemical markers of bone metabolism [110]. Leisure time PA was only moderately related to BMD, and the significance was lost after controlling for other confounders such as age and smoking. The men who had higher lifetime leisure activity scores had higher lumbar spine area and width, as well as femoral neck area, which is indicative of adaptations to mechanical loading [110]. Women with higher lifetime occupational scores, indicating that they were more active, had higher lumbar spine BMD. This relationship was not evident in the men, as the most occupationally active actually had lower BMD values than those who were least active. This anomaly could be partly explained by the men participating in occupational activities that overloaded the musculoskeletal system causing damage [110]. This study included a small sample number for each age strata (ranging n=7 for 80-85 years to n=22 for 40-49 years), and this may have affected statistical power. However, the importance of including other domains of activity, in addition to leisure time PA, such as occupational is highlighted in this study. Furthermore, the intensity of activities should be taken into account, as very high intensity activities could result in more harm than benefits to the bone structure.

Lifetime and current leisure time PA were measured for a larger cohort (n=1703) of men and women, aged 50 years or older (mean age, 73 years) by Greendale et al. [105]. A modified Paffenbarger PA questionnaire was used to determine current leisure time activity and PA levels during the teenage years, as well as at ages 30 and 50 yrs. Physical activities were classified as mild, moderate or strenuous, based on the intensity of the activity. When data for the men and women were combined, lifetime PA was positively correlated to total hip, femoral neck, intertrochanter, and greater trochanter BMD [105]. Furthermore, when the participants were classified according to tertiles of lifetime physical activity, a dose response relationship with hip BMD was found. Conversely, lifetime PA was not related to radial BMD. These findings once again support those of Korpelainen et al. [109] who found that the adaptation of bone to exercise is site specific.

More recently Mickelsfield et al [111] investigated the relationship between lifetime PA and BMD in women from the black African and Mixed Racial Ancestry groups. Lifetime PA was quantified for household, occupational and leisure time PA, for four age epochs (14-21 years; 22-34 years, 35-50 years and > 50 years) [111]. Household and total energy expenditure between the ages of 14 and 21 years was significantly associated with lumbar spine BMD ($r=0.22$ and $r=0.18$, respectively, $p<0.05$). Furthermore, activities associated with transport such as walking and bicycling during the same age epoch were associated with proximal femur BMD [111]. These findings underscore the importance of PA in the adolescent years, during which time, bone mass is being accrued. However the participants in Mickelsfield and co worker's study were younger than 60 years. Thus, the association between lifetime PA and BMD in women older than 60 years from these ethnic groups still needs to be established. Furthermore, the BMD was measured using the DXA, which is not as accessible as QUS in these communities.

Thus the effects of both current and lifetime exercise on BMD in older adults have generally been shown to be protective, although there is a lack of consistency in the results. Tools used to measure PA and the inclusion or exclusion of activity domains (e.g., housework, occupation and leisure) and their relationship with either BMD, measured by DXA, or BUA and SOS measured by QUS, further complicates the interpretation of and collation of the various research studies. In addition, most of the previous studies focused on white North American or European women, highlighting the need to establish the relationship between current and lifetime activities and BMD in differing ethnic groups, and representing a more diverse demographic distribution. Mickelsfield et al. [111] found an association between lifetime PA and BMD in South African women younger than 60 years, from the Xhosa speaking and Mixed Ancestry ethnic groups. Thus the potential benefits of PA on BMD in older women (> 60 years) using quantitative ultrasound measures, which are more accessible than DXA, still need to be determined.

1.6. Functional impairment and frailty

The importance of BMD relates to, in part, the increased risk of fracture with falling in older adults, and the morbidity sequelae following fracture, included loss of functional independence and frailty. Once older adult experiences a fall and sustains serious injury, their functional status may change, resulting in them being defined as disabled or frail. However, there are a number of other factors that contribute to the functional decline in older adults, which may lead to decreased independence and increased disability.

Therefore, studies that have enrolled older subjects across a wide spectrum of physical performance have found consistently that physical performance is associated with disability or functional impairment, and frailty. The parameters used to measure functional impairment have included gait, balance, muscle strength and range of motion, and assistance required with activities of daily living (ADL). However, frailty has been difficult to define [112] and is often used interchangeably with disability [113]. The following section of the literature review will firstly, seek to differentiate between disability and frailty, and secondly explore the physical parameters associated with these two conditions.

1.6.1. Definition of disability and frailty

Although disability and frailty are two separate clinical conditions, they are interrelated with each other [113]. There is a high prevalence of disability, which increases progressively with age [113], 2004). Disability, which is due to a loss of function [112], has also been defined as difficulty in performing ADL and instrumental activities of daily living (IADL) tasks independently [113;114]. Consequently, the older adult may need the assistance of one or two people to perform a task, or although they can complete the task on their own, it is with difficulty [113].

The condition of disability may be related to a single event, such as a fall or a stroke [112]. In this case, the previously independent individual may lose some of their functional ability, but recover sufficiently to perform daily activities, albeit with more difficulty than before the adverse event. Stable disability is a condition in which the individual's function, although compromised, remains constant, and there are no or minimal health problems [112]. This is in contrast to unstable disability that occurs when the individual's functional ability varies significantly due to an external or environmental factor, such as decreased independence resulting from a change in medication [112]. Delaying the onset of disability is of great importance from a public health standpoint, as disability has been identified as a risk factor for morbidity, hospitalization and the need for supervised care, which all contribute to increased medical costs [113;115].

Frailty has been described as one of the causes for unstable disability [112;113]. Fried and colleagues describe frailty as "a state of high vulnerability for adverse health outcomes, including disability, dependency, falls, need for long term care and mortality" [113]. Therefore, the frail individual is likely to experience increased disability, decreased function and even death as a result of minor external or environmental stresses [112]. Components of frailty include loss of reserve, feebleness, vulnerability and the presence of compromised function without overt disease necessarily being present [112]. In addition, functional dependence, slow gait speed, poor muscle strength and endurance, low levels of PA, weight loss and under nutrition are all associated with frailty.

Measuring frailty is complex, however physical performance measures such as the timed up and go and sit to stand tests, are useful tools to measure functional ability and also to predict disability [112]. Other measures of frailty are related to clinical conditions, such as cognitive function, incontinence and also the occurrence of frequent falls [112]. Strawbridge et al. defined frailty as a condition determined by an individual's decreased ability and independence in two out of five areas of function [116]. These areas of function were identified as physical, nutritive, cognitive, vision and hearing [116]. This definition enables those working with older adults to identify those who are either frail, or at increased risk of frailty [115]. Thus frailty is a multi- dimensional condition, with a number of factors contributing the presence and severity of frailty.

Even though frailty and disability have not always been consistently defined, the onset of these conditions adversely affects the older adult's quality of life [115]. By identifying the factors that place the older adult at risk for these conditions, the progression of disability and frailty could be delayed, allowing the individual to remain functionally independent for longer.

1.6.2. Classification of frailty

Ho et al. classified community dwelling individuals at high versus low risk of frailty and compared the health, habitual PA and functional abilities between the two groups (n= 37 and 42, respectively) [115]. Classification of frailty was based on self-reported difficulties in physical, nutritional, cognitive, vision and hearing domains as described by Strawbridge et al. [116]. The functional ability assessment encompassed static and dynamic balance, mobility in the timed up and go test (and two additional modifications of this test), range of motion, grip strength and the sit to stand test. Those classified as high risk were older (mean age74.1 ± 6.1 versus 69.8 ± 7.8 years) and a greater percentage reported "poor health" status (30.3% versus12.5%) than those in the low risk group. Moreover, the high-risk group was 2.5 times less likely to be physically active than the low risk group and also 3.1 times more likely to experience a decline in habitual PA over a one-year period [115]. Thus the importance of maintaining incorporating or maintaining PA as part of the older adult's lifestyle is highlighted in this study as it can play a role in health status and also delaying the onset of frailty [115].

Furthermore, those in the high-risk group had significantly poorer performances for the functional abilities tests than the low risk group. This is illustrated by the increased odds of the high-risk group performing below the mean value for all the tests, except those for muscle strength. For example, the odds ratio for achieving scores below the mean value in the high-risk group was 7.69 (95% CI: 2.74-21.58) for the timed up and go test, 4.42 (95% CI: 1.76 – 11.10) for the tandem balance, 3.34 (95% CI: 1.27 – 8.77) for tandem gait, 2.32 (95% CI: 0.96 – 5.64) for the sit to stand test. Similar results were obtained for range of motion, upper extremity control and activities of daily living. Conversely, the high-risk group had comparable performances in the muscle strength assessments compared to the low risk group. Ho and colleagues attributed this finding to the older adult maintaining a sufficient amount of strength, above a threshold, that enables them to complete ADL [115]. The poor performance in high-risk group could be related to their lower levels of PA since it plays a role in maintaining functional ability [115]. These findings also provide further evidence that functional tests are able to discriminate between older adults with varying disability levels and they also play a role in differentiating between those who are at high versus low risk for frailty. By identifying those at high risk for frailty, specific interventions, can be implemented so as to delay the onset of frailty.

1.6.3. Factors associated with disability and frailty

Functional tests enable the health care worker to quantitatively and objectively measure an individual's function, and to identify domains that may be limiting or that may benefit from intervention. Factors that are related to frailty and disability include muscle strength, balance, level of assistance required with daily tasks and gait [117].

1.6.3.1. Muscle Strength

Similar to BMD, muscle strength peaks between 20 and 30 years after which it slowly declines until middle age (45-50 years) [118]. However, from age 50 years to 80 years, the rate of decrease in muscle strength is rapid, with a decline of approximately 12-15% per decade [118]. The decline in muscle strength begins earlier in the lower extremities, although the percentage difference in muscle strength between young and older men and women is similar for the upper and lower extremity muscle groups [118].

The loss of muscle mass reported in cross sectional studies is less than that found in longitudinal studies [118;119]. Frontera et al. conducted a 12-year longitudinal study on 12 men (initial mean age 65.4 ± 4.2 years) to determine age related changes in strength of the knee and elbow as well as changes in skeletal muscle size and function (quadriceps and vastus lateralis) [119]. Participants experienced a 23.7 to 29.8% decrease in knee flexor and extensor muscle strength, as measured by an isokinetic dynamometer. The elbow flexors and extensors exhibited a slightly lower loss in muscle strength, 19.4 and 16.4%, respectively [119]. In addition to the decline in strength, the cross-sectional area (CSA) of the thigh decreased between 12.5-16.1% over the 12 years. Similarly, Lexell reported that older men and women had 25-30% smaller quadriceps CSA compared to the younger men and women [120]. Furthermore, baseline muscle strength and the 12-year decrease in CSA, were significantly associated with the decrease in muscle strength [119].

The intrinsic changes in the muscle that occur with aging include a reduction in mostly Type II fibers which contributes to the muscle atrophy and reduced muscle strength [120;121]. The decline in Type II fibers results in increased time required to develop the force needed for a task [122]. Furthermore, older adults recruit a greater percentage of their muscle fibers to complete a given task, compared to younger individuals, which results in earlier fatigue and decreased function [121]. Accordingly, the decline in muscle mass is only partly attributed to age-related declines in PA, since age related decrease in the muscle fibers and atrophy in the remaining fibers are irreversible [123].

Reduced muscle strength associated with ageing has been linked to the associated decline in functional capacity [124;125]. A deficit in muscle strength may only become apparent to the individual when they experience difficulty in performing a task [126]. Thus the ability to perform a daily task such as lifting a bag becomes harder and harder as muscle strength decreases, until a threshold is reached and the activity can no longer be performed [127]. Lower extremity muscle strength is an important component of efficient mobility, since these muscles need to generate sufficient torque during an activity such as walking [126]. Even though the joint torque required for many ADL is not large [128] if it is insufficient at functional limb velocities, both gait and balance may be adversely affected [126]. In addition, the older adult uses a greater percentage of their maximal muscle strength to perform daily tasks [122]. Consequently, many older adults gradually experience difficulties with mobility and require assistance with activities of daily living due to the impaired muscle strength [120].

Indeed, reduction in lower extremity muscle strength has been associated with reductions in walking speed [124;129]. Brown et al. compared muscle strength values obtained from a handheld dynamometer (upper body strength) and an isokinetic dynamometer (hip, knee musculature) to functional tasks (rising from a chair, gait speed, and completion of an obstacle course) [124]. The summed muscle strength values for the hip and knee extensors as well as the plantar flexors were significantly associated with gait speed (r=0.632) in the mild to moderately frail men and women (n=16, mean age 80.9 years) participating in the study. There were no significant associations between any of these muscle groups and walking speed when analyzed separately [124]. Conversely, knee extensor muscle strength was associated with walking speed in the healthy sedentary participants (60-72 years). The difference between the mildly frail and healthy participants was attributed to the frail having slower walking speeds [124]. Walking speed and stride length, which are indicators of gait quality, has been reported to be 65% and 55% less, respectively, in older adults who are classified a "fallers" compared to those who have never experienced a fall [126]. Therefore, preservation of muscle strength and gait will assist with maintaining functional ability in older adults [130]. Since there are various measures of functional ability, the assessment of functional ability will be discussed before discussing the effectiveness of intervention programs on these parameters.

1.6.3.2. Functional Ability

1.6.3.2.1. Gait

Gait has been associated with balance and Cronwell and Newton investigated the relationship between these two parameters in older (76.2 ± 6.9 years) and younger adults (26 ± 3.4 years) [130]. The participants' balance was measured using the Berg Balance test (BBT), which is comprised of 14 tasks that are scored on a scale of 0-4 points, with a higher score indicating better balance. Each participant's gait was assessed as they walked 10m across a room (repeated three times) using the MacReflex motion analysis system. The younger adults had a significantly higher BBT score and faster walking velocity indicative of better gait and balance. The BBT task, stepping on a stool, was significantly and inversely associated with walking velocity in the older adults ($r=0.58$, $p<0.05$). Similarly, Wolfson et al. found that the incidence of falling was related to stride length and walking speed [126]. Furthermore, the older adults took more steps, which results in an increase in the double stance phase of the gait pattern, thereby increasing stability [130]. The increased stability, in turn, makes up for the age-related loss in balance and could potentially play a role in the prevention of falls [130]. The prevention of falls is an important facet of aging, since approximately 30% of older adults fall at least once, it accounts for 87% of all fractures in older adults [128], and the occurrence of multiple falls has been identified as a marker of frailty [131].

1.6.3.2.2. Sit to Stand / Chair rise

The ability to rise from a chair has also been identified as one of the many activities that contribute to an older adult remaining functionally independent [132;133]. Physiological parameters related to performance have been previously investigated [132-135]. Difficulty in rising from a low chair (14-inch / 35 cm high chair) has been significantly associated with hip, knee and ankle muscle strength [124]. Similarly, Knutzen et al. found that the linear combination of plantar flexion, hip adduction and leg press strength was associated with chair rise performance ($r=0.42$) in a group of older adults ($n=143$, 60-87 years old) [122]. Functional reach, which is a marker of dynamic balance, was also significantly associated with chair rise, ($r=0.38$; $p=0.004$) in this sample.

Factors relating to sit to stand performance were evaluated by Schenkman et al. among men and women older than 65 years [132]. All the participants were unable to descend stairs "step over step" without using any support, which indicated that they had some functional impairment [132]. The ability and time taken to rise from chairs varying in height, 33 to 58cm, were recorded. The chair rise performance was compared to muscle strength for the knee flexors and extensors, and the ankle plantar and dorsi flexors measured on the Cybex dynamometer. In addition postural sway was measured as a marker for static balance, and function reach for dynamic balance. The bivariate analysis revealed that both lower extremity muscle strength and functional reach were related to successful chair rise performance for the lowest height, r= -0.64; p <0.001 and r= -0.38; p=0.004, respectively. Lower extremity strength remained a significant predicator of successful chair rise performance (lowest chair height) in the multivariate analysis that included functional reach, range of motion and biomechanical parameters. The multivariate model accounted for 47% of the variance in performance in this sample (r=0.68; p<0.001). Therefore, both strength and balance contribute to chair rise performance, although the contribution from strength is greater.

Additional factors related to sit to stand performance including visual acuity, visual contrast sensitivity, lower limb proprioception, peripheral tactile sensation, reaction time, postural sway and balance were investigated by Lord et al. [134]. Their findings were in agreement with that of Schenkman et al. as muscle strength, particularly quadriceps strength, was the most important determinant (β = -0.167; p=0.002) of sit to stand performance in a random sample of older community dwelling Australians (n=669; $\geq$ 75 years) [132]. The findings of the two studies are similar despite the fact that Schenkman et al [132] evaluated chair rise, i.e. only the ability to stand from a chair, while Lord et al. [134] evaluated sit to stand performance, i.e., ability to stand and sit five times. However, more than half the variance in performance was attributed to sensorimotor, balance and psychological factors [134]. The sensorimotor factors were visual contrast sensitivity, lower limb proprioception, tactile sensitivity and reaction time. Balance measures related to performance were postural sway, while pain, anxiety and vitality were the psychological parameters [134]. Therefore, sit to stand performance is influenced by more than muscle strength as sensorimotor, balance and psychological parameters also contribute to performance [134].

Brach et al. further investigated the peak muscle activity, total muscle activity and time to peak muscle activity from surface electromyography (sEMG) testing during the chair-rise performance [135]. The women participating in this study were 73.9 ± 3.9 years old and able to rise from a chair without the use of their arms, suggesting a higher level of functioning than Schenkman et al's [132] participants. Peak muscle activity was greater for the standing compared to the sitting component. On the other hand, time to peak muscle activity was longer for the sitting than the standing component. The slope of the rise in muscle activity, which was most representative of muscle activity during chair-rise performance, was calculated using the magnitude and timing components of quadriceps muscle activity [135]. Self reported functional impairment for the chair rise was associated with lower peak muscle activity for both sitting and standing and also a gentler slope during standing [135]. Therefore measures of muscle activity and recruitment during a functional task provide additional information on the risk and onset of early functional decline than physical performance tests alone [135]. Furthermore, these studies [122;132;134;135] have shown that balance and strength are contributors to successful chair rise performance in both healthy and functionally impaired older adults.

1.6.3.2.3. Grip Strength

The age associated decrease in muscle strength can be measured in the upper body, by using a hand held dynamometer to determine grip strength. As a result, grip strength has been widely used as a measure of functional ability and frailty [136].

In order to determine whether grip strength is a useful single marker of frailty, Syddall et al. compared grip strength to chronological age in older adults, 64-74 years old (n=717) [137]. Gender, age and height were all significantly associated with grip strength which was reflected by the higher scores obtained by the men, the younger and also the taller participants. Furthermore, decreased grip strength was related to decreased cognitive function, higher hearing threshold, poorer visual acuity, increased risk of gait abnormalities, and self reported arthritis for both the male and female participants [137]. The relationship between grip strength and these markers of aging remained significant even after adjusting for age. Thus, Syddall and coworkers suggest that grip strength is a more useful single marker of frailty than chronological age alone. Moreover, grip strength, was significantly related to all cause mortality in the men, but not the women, during the 10 year follow up study [137].

Al Snih and coworkers investigated the relationship between had grip strength and mortality in older (≥ 65 years) Mexican-American men and women [138]. Grip strength was measured using a hand held dynamometer, functional disability (Katz ADL) and mobility (8-foot timed walk) was assessed in 2 488 community dwelling Mexican-Americans. Similar to other studies, handgrip strength was lower in the women, who also reported more ADL and IADL disabilities than the men. During the 5-year follow up period, 39% of the men and 42% of the women who died were in the lowest quartile for handgrip strength at baseline [138]. The risk of death increased significantly for those in the lowest quartile, compared to those in the highest quartile for both the men and women. Among the men, the hazards ratio was 2.47 (95% CI: 1.63-3.73) for those in the lowest quartile, 1.71 (95% CI: 1.13-2.60) in the second quartile and 1.22 (95% CI: 0.77-1.91) for those in the 3rd quartile when compared to the stronger men in the highest (4th) quartile. Similarly, the weakest women in the first quartile had a hazards ratio of 2.89 (95% CI: 1.87-4.49) for increased risk of mortality compared to those in the highest quartile. Likewise, the women in the second and third quartiles had increased risk for mortality, HR = 1.91 (95% CI: 1.22-3.01) and 1.53 (95% CI: 0.97-2.44) compared to in the highest quartile [138]. Furthermore, for every 1kg decrease in handgrip strength, the risk over mortality increased 3%, even after adjusting for gender, age, marital status, education and the presence of medical conditions [138]. These results suggest, that in addition to handgrip strength being used as a marker of disability, it may be also used as a measure for the risk of mortality. This may be valuable from a public health perspective, since the hand held dynamometers are portable, relatively inexpensive and easy to use, allowing for extensive field-based testing.

1.6.3.2. Peak Performance Test (PPT)

Brown et al. investigated the association between muscle strength, range of motion, co-ordination and balance with the results obtained from the PPT, sit to stand and Romberg balance test in community dwelling men and women older than 77 years [117]. The PPT consists of seven items that are all associated with disability, loss of independence and early mortality [117]. The modified PPT assessment used in the trial of Brown et al. included climbing 10 steps, climbing four flights of stairs, turning 360^0, picking up a small coin, putting on and taking off a coat and lifting a book onto a shelf, as quickly as possible [117]. For the Romberg balance test, participants stand for a maximum of 10 seconds with their feet together, then in the semi tandem and tandem stance [51]. The results from these tests were compared to isokinetic muscle strength tests, hand held dynamometry, range of motion, additional balance assessments (including functional reach and an obstacle course) and gait analysis measures [51].

The PPT score distinguishes between those who are not frail (score = 32 or more out of a maximum of 36), mildly frail (score = 25-31) and moderately frail (score = 17-24). For the bivariate analysis, balance, preferred gait speed, fast gait speed, and shoulder flexion and external rotation (measures of flexibility) were all significantly associated with the PPT scores

[117]. For the multivariate analysis, the variance in the PPT scores was best explained by performance in the obstacle course, time in which the tandem stance is maintained, hip abduction strength and co-ordination [51]. The association between the PPT and these variables was $R^2 = 0.727$. Of these variables, balance ability had the strongest association with the PPT score, although not all the balance tests were related to the PPT. For example, the obstacle course was highly correlated to PPT scores, but the one leg stand was not. Thus, the selection of protocol should include tests that are sensitive enough to discriminate between varying degrees of disability [51]. Brown and coworkers have therefore shown that because frailty is multidimensional, more than one domain should be evaluated when determining the degree of frailty and disability in an individual or population [117].

1.6.3.3. Activities of daily living (ADL) and Instrumental activities of daily living (IADL)

The ability to perform ADL, IADL and mobility tasks independently has been defined as physical function [136]. Thus physical disabilities and impairments such as reduced muscle strength and impaired gait, can contribute to the decrease in physical function [136].

The Frailty and Injury: Cooperative Studies of Interventions Trial (FICSIT) is a multi center collaborative project based in the United States [114;139;140]. FICSIT comprised of eight studies, aimed at measuring the effectiveness of interventions on outcomes including functional status and quality of life [114;139]. Functional disability (IADL impairment) was compared to measures of physical performance, which included grip strength, gait velocity, sit to stand test and balance, in community dwelling older adults (n=2190; 74.7 ± 6.3 years old) from six FICSIT sites [114]. Judge and coworkers chose IADL, based on Lawton's questionnaire, as the dependant variable, since impairments in IADL often precede those for ADL [114].

More than three quarters (78%) of the participants did not require any assistance with the IADL's, and were classified as independent [114]. The participants who were dependant in one or more IADL's, reported housework and shopping as the activities most frequently requiring assistance. An increased IADL score was significantly related to slower gait speeds for both the frail and more independent participants. For every 10 participants experiencing a 0.1 m s^{-1} decrease in walking speed, there would be one additional IADL task requiring assistance [114]. Similarly, grip strength was inversely associated with IADL score, after adjusting for covariates including the mini metal state exam [141] and the Tinetti falls [142] efficacy questionnaire scores. Furthermore poor sit to stand and balance performance for the parallel, semi tandem and tandem stances, were related to higher IADL scores, particularly when all the sites were combined in the meta-analysis. Therefore these performance-based tests, which are relatively easy to administer, are predictors of IADL dependency for both fully dependant and functionally impaired older adults.

Similar results were obtained when investigating the relationship between ADL's and functional impairment [143]. Rockwood et al. found that impairment in ADL was associated with increased odds (OR = 9.10) of being institutionalized [143] in Canadian older adults. However, the relationship between functional impairment and placement in institutionalized care was reduced when covarying for other factors. Thus, together with ADL impairment, the presence of dementia, female gender, a diagnosis of stroke, Parkinson's diseases and diabetes mellitus, placed the individual at increased odds of being institutionalized [143]. These findings support those already discussed, that when measuring disability or frailty, more than one domain should be included in the assessment.

The relationship between physical function and disability was more recently investigated by Brach and VanSwearingen in a group of community dwelling men older than 60 years [136]. Physical impairment was quantified from the tests for maximal grip strength, ankle flexibility, and the modified sitting step test. Gait speed and stride length, which reflect mobility, was assessed as the participant walked 6m at a self selected pace, and was categorized as a measure of disability. An additional measure of disability was fall risk, which was categorized according to the modified gait abnormality rating scale (GARS-M). This scale is comprised of 7 items which were evaluated by a physical therapist who watched a video tape of the participant walking at a self selected pace on a smooth surface [136]. Furthermore, physical function was measured using the 7-item PPT, which includes assessment of daily activities. The PPT has previously been validated as a measure of ADL, IADL and measures of mobility and balance [144].

This study demonstrated that gait speed, fall risk and grip force were independently related for physical function (PPT scores) [136]. Furthermore, four domains of physical function that explained 68.2% of the variance in physical function were identified as mobility, coordination, fitness and flexibility [136]. Thus the evaluation of impairment in older adults should include these domains, to provide a measure of physical functioning in the older adult. These measures will allow for the identification of domains that require improvements, and thus assist with the implementation of an appropriate intervention to delay the onset of disability or placement at an old age home [136]. (The effect of PA interventions on physical performance will be discussed in section 1.6 of the literature review).

1.6.3.4. Socio-demographic Factors

Socio-demographic factors which include age, gender, racial group, place of residence, education, home ownership, income and family composition were investigated as determinants of disability among older Brazilian adults [144]. The data used for this study were obtained from the Brazilian National House survey and comprised of a nationally representative sample of 28 943 men and women aged 60 years and older. Although a number of daily tasks were evaluated, difficulty in walking more than 1 km was used as a marker of mild disability, difficulty in walking 100m was moderate disability and difficulty in feeding and self-care was rated as severe disability [145]. The prevalence of disability was highest among the women and the older participants. In an age-adjusted model, female gender, housing conditions, education, urban/rural residence, family income and sanitation were all associated with the prevalence of disability [145].

In the multivariate model, lower income and education were associated with increased risk of disability. Twenty two percent of those in the lowest quartile for income and 23.6% of the illiterate participants reported difficulty in walking 100m, while only 11.6% and 12.7% of those in the highest quartiles for income and education, respectively, reported disability. This study is particularly useful in the South African context, since both countries have an unequal distribution of wealth, and are developing nations. Furthermore a large proportion of older adults from previously disadvantaged groups, the Xhosa and also those of mixed racial ancestry, did not have access to formal education. In addition, the monthly State pension, R820 (± $ 126) in 2004, is the only source of income for the older adult and their family, placing them in very low socio economic groups. Because these factors are related to disability, and there is a paucity of disability data from Africa, further investigation is necessary.

Melzer and Parahyba's [145] findings are supported by those of Grundy et al. [146] even though the latter study was conducted in the United Kingdom, a developed and economically stable region. Socio-demographic factors that have been linked to increased disability in the UK, include those individuals previously employed to perform manual labor, local authority tenants and education [146]. Grundy and coworker's longitudinal investigation also identified lower socio-economic status, self-rated health, age and gender as variables associated with increased prevalence of disability after five and a half years [146].

1.6.3.5. Nutrition and cognitive function

Chin A Paw et al. [147] identified PA and malnutrition as two of the major determinants of frailty. This is in part due to the fact that inactivity may cause a decrease in appetite and reduced dietary intake, which in turn results in malnutrition, muscle dysfunction and further inactivity. Although poor nutritional intake and cognitive function is related to the onset of frailty and disability, the scope of this literature review does not extend to the discussion of this variable.

1.6.3.6. Summary

The identification of older adults who have functional impairments or who are at risk of frailty and disability is an important step in the maintenance of independence in the older adult population. Thus the identification the areas of weakness and impairments, will enable health care workers to establish which the functional impairments requires attention [136]. Thereafter, an appropriate intervention program can be implemented so as to improve functional ability and thus delay the onset of frailty and further disability [136]. This is supported by the findings of Rantanen and colleagues who established that severe motor disability was associated with lower PA, which in turn was associated with poor muscle strength [125]. Thus, PA intervention programs can play an important role in maintaining independence in the older adult. The paucity of data for older adults from developing countries such as South African, particularly those from lower socio-economic groups, warrants further investigation to identify the prevalence and markers of disability. These countries typically have limited access to health care [145], and the effectiveness of exercise intervention can assist in the maintenance of health and function in the older adult.

The reduction in muscle strength and the functional consequences such as impaired gait and chair rise can be improved upon with PA interventions since they have been associated with the maintenance of muscle strength and function [124]. Indeed, physically active older adults experience only moderate losses in skeletal muscle mass [121]. The nature of the intervention warrants further investigation in order to design the most effective means of increasing or maintaining muscle strength, balance, gait stability and functional status.

1.7. Effectiveness of intervention studies of physical activity in older adults on health and functional outcomes

1.7.1. Introduction

Although the benefits of PA on functional performance, disability, fitness and health have been recognized, the optimal level of PA for older adults requires further investigation [49]. The intensity, frequency and duration of the PA intervention all play a role in attaining health and functional benefits. The following section of the literature review will describe intervention studies of varying intensities and duration and their effects on muscle strength and the functional ability of the older adult. Table 1.4 provides an overview of some of the PA intervention programs that have been investigated in the older adult population.

1.7.2. *Muscle strength and endurance, and functional performance*

1.7.2.1. Combined strength and endurance training

These results suggest that PA intervention in older adults could play an important role in maintaining mobility [52] [125;148]. However, further investigation on the intensity and mode (e.g. strength or endurance training) is required to determine the required PA dosage for optimal benefits. An improvement in muscle strength, endurance and balance also plays an important role in improving the older adults' functional status and their ability to perform daily tasks independently. Rubenstein and co-workers investigated the effects of a 12-week exercise intervention on muscle strength, gait, balance and functional performance in men ($\geq$ 70 years) at risk for falls [50] (Table 1.4). The risk factors for falls were identified as lower extremity muscle weakness, impaired gait, impaired balance, or more than one fall in the previous 6 months [50]. Participants were randomly assigned to either the intervention / exercise or control group. The exercise group (n=31) participated in three, 90-minute strength and endurance exercise sessions per week, using ankle weights, elastic bands and rubber balls as resistance, while the control group (n=28) maintained their usual activities.

The 12-week intervention resulted in significant improvements in muscle strength, particularly for knee flexion, among the exercise group, and no changes were observed in the control group. Moreover, gait and endurance improved significantly in the exercise groups as evidenced by improvements in the 6-minute walk test distance, which were 48m in the exercisers and only 12 m for the controls [50]. Of greater importance however, the functional performance of the exercise group improved significantly while there were no changes in the control group. This is reflected in the sit to stand test, which a proxy for leg strength, where the exercisers were able to complete more repetitions after the PA intervention. Incorporating PA in the lives of those older adults already at risk for falls, may further increase the risk for falling due to greater exposure to environmental hazards such as uneven walking surfaces [50]. Even though, 38.7% of participants of the exercise group did experience a fall, it was significantly less (per 1000 hours of activity) compared to the control group. Therefore, older adults, even those at risk for falling, are able to benefit from structured exercise programs as evidenced by improved endurance and muscle strength. However, the intervention in this study involved exercise training three times weekly for 90 minutes per session, and may be too time consuming and demanding for the older adult.

King et al compared the effectiveness of a shorter (60 minute) combined endurance and strengthening exercises (Fit and firm) with stretching and flexibility (Stretch and flex) training in older adults recruited from Sunnyvale California population records. Both the fit and firm and Stretch and flex group were encouraged to two home and two class based exercise sessions per week. The Fit and firm exercise group experienced significant improvements in endurance and strength, while the Stretch and flex group's flexibility increased while "bodily pain" decreased after the 12-month intervention period [148]. Thus, we need to establish if less frequent and shorter duration intervention programs are able to achieve similar benefits to the longer and more frequent interventions. In addition, the effectiveness of intervention programmes varying in intensity and frequency may be different among diverse groups of older adults. Consequently, further investigation could help to determine which groups of older adults would benefit from different types of intervention programmes.

1.7.2.2. Supervised versus home based strength and endurance training

Although the previous intervention studies have shown that PA improves functional ability, they have not looked at specific performance variables associated with frailty. Brown et al. identified factors associated with risk of frailty such as impaired gait, decreased flexibility, decreased muscle strength and balance and co-ordination, and investigated the effects of strength and endurance training on these outcomes in community dwelling men and women, living independently but with some difficulty [51]. The randomized study design incorporated two groups, where those belonging to the supervised exercise group (n=48, mean age 83 ± 4 years) were compared to those participating in a home exercise group (n= 39, mean age 83 ± 4 years) who only performed stretching exercises. The exercise group performance 22 exercises three times per week using therabands and hand held weights for resistance. The exercises which formed part of the intervention program were designed to incorporate all the muscle groups and had flexibility, balance, reaction time, co-ordination components, with strength training forming a smaller portion of the exercise session. All the participants of this study were community dwelling and required varying degrees of assistance with some mobility tasks.

Outcome measures before and after the intervention included the PPT, which was administered to determine the degree of impairment or frailty [51]. In addition, strength, balance, flexibility and gait were assessed. The exercise group improved their PPT scores significantly after the three months of low intensity exercise, while the home (control) group's scores did not change. Furthermore, muscle strength, particularly leg strength, and balance improved significantly in the exercise group. However, range of motion improved in both the exercise and control group. This finding is not surprising since the home group's program comprised of stretching exercises. Although the stretching exercises improved flexibility in the control group, there were no other improvements, indicating that range of motion exercises are not sufficient to enhance the older adult's functional ability and mobility status [51]. The importance of this study's findings is that low intensity exercise can improve function, even in mobility impaired older men and women. The improvements in strength and balance are associated with improvements in functional ability, which is in agreement with Rubenstein et al. [50] findings.

More recently, in a similar, but randomized control trial was conducted by Barnett and colleagues to establish if structured supervised exercise, in conjunction with home based exercises, will improve functional ability and health status in community dwelling older adults "at risk" [149]. The participants of this study was similar to that of Brown et al. [51] as they (n=163, >65 years) had one or more functional impairments that are related to increased risk for falling. However, Barnett et al's [149] intervention was longer, since participants re-evaluated at six months, versus three months in Brown et al [51]. In addition, their exercise group participated in a weekly structured exercise program in addition to home-based exercises, while the control group did not perform any exercise [149] (Table 1.4).

Muscle strength, walking speed, reaction time and health did not improve significantly in the exercise group after 6 months. The lack of improvement in these parameters was attributed to the exercise intervention focusing primary on balance training, and to a lesser extent on strength and walking [149]. However, similar to Brown et al. [51] the exercise group's balance improved significantly and the rate of falls was lower than that of the control group after six months [149]. Furthermore, the number of falls causing injury was significantly less for the exercisers. Therefore, both these studies [51;149] have shown the beneficial effects of PA on reducing the risk of falls in an "at risk" group of older adults. However, there are inconstancies regarding the benefits of exercise training on strength and other measures of mobility such as walking performance. For example the exercise intervention for Brown et al's [51] study resulted in significant improvements in muscle strength whereas no improvements were observed for Barnett et al [149].

The implementation and effectiveness of home-based exercise programs is promising, since they overcome possible barriers to PA such as lack of transport and accessibility. The effects of a 6-month home-based intervention program (single blind randomized control trial) on functional ability were investigated by Nelson et al. [150] (Table 1.4). These researchers also used the PPT to assess functional ability in addition to the EPESE battery of tests in a group of men and women with self reported functional disability, older than 70 years. Balance was measured using the tandem walk and one-legged stand, while leg, arm and shoulder strength were assessed with the 1RM, and the hand held dynamometer for grip strength. Their findings were similar to that of Brown et al. (2000) and Barnett et al. (2003) because gait, 6-minute walk distance and muscle strength did not improve significantly in the exercise group [150]. Conversely, the exercise group improved their PPT and EPESE scores by 6.1 ± 13.4% and 2.8 ± 13.6% respectively, indicating that they improved their functional performance. Furthermore, both tandem balance and the one-legged stand performance improved significantly after the 6-month home based exercise intervention. Thus, home based, low intensity exercise programs using dumbbells and ankle weights, are beneficial to the older adults with moderate to severe lower body functional impairments. However, further investigation in warranted determining whether this type of intervention is beneficial to those without functional impairments.

The duration and frequency of the exercise program to achieve health and functional measures is another question that warrants further investigation. "More exercise for seniors (MbvO)" is a Dutch moderate intensity program for older adults [151]. The gymnasium-based exercise sessions include both aerobic and strength training components, and are approximately 45 minutes long. Older adults between the ages of 65 and 80 years, living independently were randomly assigned to the intervention groups or control group in order to compare the effectiveness of one or two exercise sessions per week with each other and the control group. Outcome measures included seven items from the PPT, a detailed subjective assessment of assistance needed in daily activities, chronic diseases and habitual physical activity [151]. Although there were no significant group by time effects between the groups exercising once and twice per week, those in the twice-weekly group whose PA levels were below the median value at baseline, experienced significant improvements in health related quality of life questionnaire. There were no significant improvements in functional status in either of the groups after the 10-week intervention. The duration of the intervention may have been too short (10-weeks) for functional improvements to occur. In addition for older adults who have high initial levels of functioning, one or two exercise sessions per week may be insufficient to achieve significant health and fitness benefits. These authors concluded that moderate intensity exercise results in short term health benefits among those who are most inactive [151]. From a public health perspective, it is therefore important to encourage sedentary older adults to participate in PA or exercise programs at least twice per week.

1.7.2.3. Strength Training Intervention Programs

Since balance training does not result in direct improvements in muscle strength [51], there is a need to determine whether strength training can result in improvements in both balance and muscle strength. Schlicht et al. investigated the effects of an intense strength training intervention on balance, maximal walking speed, muscle strength and sit to stand performance in moderately active, community dwelling men and women older than 60 years [152] (Table 1.4). The participants who were randomly assigned to the intervention group (n=12) completed eight weeks of strength training, using gym equipment, at 75% of the 1RM for a range of lower body exercises. The results were compared to a control group (n=12), who did not perform any type of PA during the eight –week period. Leg extension and hip adduction improved significantly in the intervention group after 4 and eight weeks. Similarly, hip abduction, gluteal press and leg press muscle strength improved significantly from baseline to four weeks, although there was no further improvement from four to eight weeks. Walking speed increased in the exercise group from baseline to four weeks and baseline to eight weeks [152].

Thus very early adaptations to the strength-based intervention were evident. Both walking speed and strength are risk factors for falling [152] and the improvement in these parameters is promising. Conversely, both the intervention and control group improved in the sit to stand and single leg balance test, resulting in non-significant between-group differences at eight weeks. These findings suggest that strength training alone is not sufficient to improve balance and functional performance as measured by the sit to stand test [152]. However, the intervention period was relatively short, and the sample size of this study was small.

The effectiveness of a longer (24 month intervention), moderate intensity strength-training program was measured in healthy community dwelling men and women older than 55 years by Brandon et al. [153]. The participants were randomly assigned to either a control or exercise intervention group which performed 11 exercises using the Nautilus multi station unit. Brandon et al's participants were assessed every six months to measure muscle strength and functional ability (get up and go test, functional reach, walking up and down stairs and rising from the floor). The exercise intervention group significantly improved their muscle strength by 28% after the first six months, and maintained these changes until 24 months. Similarly, walking up and down stair performance increased significantly after six months, and continued to improve until the end of the intervention period. The exercise group improved their mean function score at six and 12 months, after which there was a gradual decline in their functional ability until 24 months. Although the functional score declined after twelve months, the functional ability was still higher than the baseline score after 24 months. The authors suggested that the small increase in functional ability may have been due to the subjects having a high functional ability score, close to the ceiling effect, at baseline, which resulted in limited opportunity for improvement.

Although the mean functional performance (sum of all functional performance tests) was significantly better than the control group at 12 months, when each of the tests were evaluated individually, there were no significant differences between the groups [153]. For example, the get up and go test, which incorporates strength, balance and agility, did not improve significantly in the exercise group when compared to the controls, whereas the mobility scores improved. In addition, functional reach and the get up and go tests, which are indicator of balance, did not improve after the 24-month intervention. These findings are similar to Schlicht et al. [152] where the intervention resulted in improved strength but not in improved balance ability. Brandon et al. findings do however, demonstrate that moderate intensity strength training has similar benefit to high intensity strength training [153].

Similarly strength training is also beneficial for frail older adults. Fiatarone et al. investigated the effectiveness of a randomized control trial in institutionalized older adults, 87 ± 0.6 years, comparing exercise combined with nutrition intervention, to nutrition or exercise intervention only with a control group [154]. The exercise intervention comprised of high intensity resistance training, for the hip and knee extensors. The subjects in the exercise group performed the resistance training at 80% of 1RM, three times per week for 10 weeks. A significant increase in muscle strength (114 ± 8 %), gait velocity (12 ± 4%), and stair climbing (28.4 ± 7 %) was observed in the exercise intervention group compared with no improvements in the control groups. Those taking the nutritional supplements did not experience in significant improvements in muscle strength and functional measures compared to those in the exercise intervention group. Thus, resistance training is beneficial to frail older adults, even after a relatively short, 10-week, intervention.

1.7.2.4. High versus low intensity strength training

Since strength training has been found to be beneficial in community dwelling and relatively independent older adults, Seynnes et al. investigated the effect of a low versus high intensity training program in frail older adults [155] (Table 1.4). Outcomes after the 10-week intervention included knee extensor strength, endurance, chair rise performance, stair climb performance and the 6-minute walk test. The participants who were randomly allocated to the high intensity group trained at 80% of 1RM, while those in the low intensity group trained at 40% of 1RM, compared to the control group who also participated in exercises, but without any additional weights. Both the intervention groups used free weights for added resistance when executing the exercises. Muscle strength increased significantly in the resistance training groups, however greater improvements were noted for the high intensity group (57.3 ± 4.8% versus 36.6 ± 5.9%). Similarly, the improvements in muscle endurance were significantly greater in the high intensity group (284.6 ± 73.5%) compared to the low intensity group (117.7%). Sit to stand and stair climbing performance also increased significantly in both intervention groups, however the percentage improvement was not significantly different between the two groups. The improvements in muscle strength were significantly associated with changes in muscle endurance, sit to stand performance and 6-minute walk distance [155].

Seynnes et al's results suggest that there is a dose response to resistance training, with higher intensity training yielding greater improvements in muscle strength and functional ability in frail older adults [155]. These results are similar to those obtained in community dwelling older adults [152;153]. However, higher intensity exercise may require more supervision to ensure the correct execution of the exercises, and from a public health perspective, it may not be feasible to implement widely and safely. Thus, when prescribing exercise to older persons, it may be beneficial to include moderate intensity exercises since the risk of injury is reduced [156]. Furthermore, the older adult is more likely to sustain physical activity behavior if the exercises are moderate intensity [156].

1.7.3. *Aerobic Capacity*

1.7.3.1. Strength training

Although strength training does not always result in improvements in balance and some measures of functional ability, its effectiveness in improving aerobic capacity warrants investigation. Hagermean et al. recruited 18 untrained men between the ages of 60 and 75 years to participate in sixteen weeks of high intensity resistance training (randomized control trial) (Table 1.4) [157]. The older men in the trained group experienced a 50.4% increase in leg muscle strength, 72.3% increase for leg press, and 83.5% increase in the half squat. Aerobic capacity, measured by peak VO_2, and time to exhaustion on the treadmill increased significantly in the trained group, while there were no changes in the control group [157]. These aerobic adaptations occurred despite the fact that only approximately five minutes of the training session was spent on the cycle ergometer, and the rest of the session was spent in high intensity strength training. Hagerman and co workers postulated that the increased muscle strength could have in part contributed to the participant's increased time to exhaustion on the treadmill and also due to the high intensity of the strength training [157]. Their participants were closely monitored throughout the intervention, so while the older men can cope with high intensity training, the cost of staff is a likely barrier when trying to implement this program in other centers.

Since strength training improved aerobic capacity in the previous study, the question arises as to whether to include mostly resistance or cardiovascular components in the exercise session to achieve optimal benefits. As a result, Kallinen et al. investigated the effects of an 18-week strength (n=16) versus endurance (n=15) program were evaluated in Finnish women between the ages of 76 and 78 years who had no contra-indications to exercise (Table 14) [158]. The strength training was performed on equipment that used pressed air as resistance, and all the major muscle groups were exercised. The intensity of the strength training increased from 60% of RM and was later increased to 75% of RM. The endurance training comprised of walking on an indoor track for 20 minutes initially, and later increasing to 30 minutes. In addition, the endurance trained group participated in step aerobics class (40 min) once per week. The strength-training group experienced a significant increase in peak power compared to the control group. Similarly, the endurance trained group increased peak power per kg body weight significantly, while the control group showed no improvements. Unlike the findings reported in Hagerman et al. [157], there were no significant improvements in maximal oxygen uptake in the strength nor endurance trained groups.

The difference in findings between Hageramn et al. [157] and Kallinen et al. [158] may be related to the latter study's intervention training intensity being lower and also the fact that the participants were only women. Furthermore, five of the participants in the exercise groups experienced health problems causing them to withdraw from the study. Thus the limited effects observed in the exercise groups may have been related to the small sample size, resulting in reduced statistical power. This study demonstrates only limited benefits from PA and suggests that strength training is more beneficial than aerobic training.

1.7.3.2. Aerobic / Endurance Training Intervention Programs

An older group of "medically stable" men and women (79-91 years) participated in another research study to determine the effectiveness of a 24-week cardiovascular training program (3 exercise sessions per week) on VO_2 and muscle strength [159]. The 24-week exercise intervention occurred after a 12-week control period. Unlike the previous study, this intervention was slightly longer and only incorporated 10 minutes of strength training using body weight and therabands as resistance, per one-hour of the aerobic training session. After 24 weeks, VO_2 max improved significantly in the women but not in the men. The men had higher baseline VO_2 and may therefore have been fitter than the women, resulting in a smaller improvement post intervention. These improvements in VO_2 are thought to positively affect the ability to maintain independence in daily activities. Knee extensor strength and leg muscle power did not improve significantly in both the men and women after the 24 weeks [159]. The only improvement in strength was for the elbow flexors, and this effect was only seen among the women. The authors therefore concluded that the 30 minutes of strength training per week was insufficient to improve strength in this sample, although the cardiovascular training resulted in improved cardiovascular fitness [159].

Aerobic exercise has also shown to be beneficial among previously sedentary frail older adults [160]. Vaitkevicius and colleagues investigated the effectiveness of a six-month moderate intensity exercise program in sedentary community dwelling men and women (Table 1.4) [160]. The intervention group participated in three treadmill or stationery cycle exercise sessions per week. Each exercise session was 20 to 30 minutes long, and participants exercised at 60 to 80% of the maximal heart rate (derived from maximal exercise treadmill test conducted at baseline). Systolic blood pressure, exercise duration, and VO_2

peak improved significantly after the six-month training program [160]. Consequently, those older than 80 years can also achieve the fitness and health benefits associated with aerobic or cardiovascular exercise.

1.7.4. Summary

Based on the previously mentioned intervention studies, the components of the exercise program should be multi-faceted, comprising of balance, strength, flexibility and endurance exercises. Furthermore, small sample sizes together with the study design and subject selection, may limit the generalization of each study's findings to other populations, and also limit statistical power.

In summary, the benefits of PA interventions are generally evident, but are not always consistent, which may be attributed, in part, to the participants' age, and the characteristics of the exercise intervention, e.g., strength versus cardiovascular, and high versus low intensity. The positive outcomes of intervention studies result in an improvement of the individuals' quality of life, since they are able to perform more daily tasks independently [51]. However, most of the research has been conducted in Caucasian populations and in developed countries, excluding subgroups like those comprising of non-Caucasian populations and individuals from lower socio economic groups [161]. Consequently, there is a paucity of data from developing countries and the African continent.

Moreover, PA intervention programs may be particularly beneficial for South African older adults, as in regional studies, using similar instruments, the levels of reported daily activity appear to be markedly lower than that reported for North Americans of similar age [9]. These lower levels of PA may be due to limited opportunities for leisure time PA due to the lack of recreational facilities (sports and recreation centers, open grassed public space, walking paths) in these communities [9].

1.8. Summary of Chapter One

The increased proportion of older adults, coupled with the decreased life expectancy for the middle-aged population due to HIV/AIDS deaths, underscores the importance of maintaining or improving the health and functional status of older South Africans. The former apartheid government socially and economically discriminated against these two population groups. Subsequently, large proportions of these older adults have low levels of education and are from the lower to middle income socio-economic groups. Ethnicity [33], low education [37] and socio-economic status [37] have been identified as risk factors for decreased levels of PA, therefore, this dissertation aims to investigate PA and its associated benefits among the Mixed Racial Ancestry and Xhosa speaking older adult population groups.

The apparent proportion of South African older adults from the Mixed Racial Ancestry and Xhosa speaking population groups who are physically active is low [9]. However, there is a paucity of data on the prevalence of PA and the associated benefits thereof, in Sub Saharan Africa. Therefore, in order to accurately measure habitual PA, tools developed specially for older adults should be identified. The YPAS has been developed for older adults, and includes activities they often engage in such as gardening, housework and walking. Conversely, the IPAQ was developed primarily for younger adults in order to determine the prevalence of PA, and also to compare habitual PA in different countries. Therefore, the first phase of our investigations, was to compare and validate these two instruments as a measure of PA in older South Africans.

Physical activity is associated with a decreased the burden of disease, particularly chronic diseases such as CAD and osteoporosis, even in older adults [49;67-70]. Current PA has been previously shown to play a role in maintaining BMD [92;102]. However, the relationship between PA and BMD has not been consistent. For example, Brahm et al. [110] found only moderate associations between PA and BMD, while Greendale et al. [105] reported significant associations between femoral BMD and PA. Furthermore, few studies have incorporated both men and women, and also those older than 60 years. Therefore, investigations exploring the relationship between PA (both current and lifetime) are warranted in non-Caucasian populations, those from lower socio-economic groups, and who had occupations involving blue collar / manual labor. Moreover, due to a lack of resources, very little information is available on the prevalence of low BMD in South African older adults from the lower socio-economic areas. Consequently the second objective of the dissertation was to investigate the relationship between both current and lifetime PA with estimated BMD in older adults form lower socio economic groups.

Decreased levels of PA have also been associated with decreased functional performance, and increased risk of disability. Various functional performance tests have previously been used to determine the older adults level of independence and subsequently their level of functional impairment. These definitions are becoming increasingly important, as most state subsidized institutions have been encouraged to only admit those classified as frail.

Previous studies have used various tests batteries and self-report or questionnaire based measures to determine the degree of disability or impairment [115;126;130;132]. However, to our knowledge, none of these tests have been performed on older adults from the Xhosa speaking population in the Western Cape. Therefore, the third objective of the dissertation was to investigate the relationship between functional performance tests and questionnaire based assessments of frailty and disability in Xhosa speaking older adults. Furthermore, we sought to compare these functional parameters to the Disability Questionnaire 98 (DQ 98). The DQ 98 is used by the local Department of Social Services to determine the urgency with which an older adult should be admitted to institutionalized care. In addition, we calculated a composite functional ability score, based on seven functional tests, and investigate the relationship between this score with habitual PA, and the questionnaire-based measures that included the DQ 98, ADL and IADL questionnaires. Because frailty has not been difficult to define [112] and has been associated with decreased functional performance [51;115], we compared two constructs of frailty with the functional performance measures.

Factors such as decreased muscle strength that occurs with aging [118-120] have been shown to play a role in increasing functional impairment [124;129]. The age associated decline in muscle strength and functional ability, can however be attenuated with regular PA [130]. Therefore, PA intervention program may play a role in improving the both the health and functional status of older adults.

Considerable research has been conducted to investigate the effectives of exercise intervention programs in older adults [50-52;125;149;150;152;153;155;157;159;160]. Many studies have shown improvements in variables such as muscle strength [50;51;155], endurance [50;155;160] and functional measures such as balance and sit to stand performance [50;51;150]. Despite these positive findings, the duration of and intensity of the intervention programs vary, and subsequently Landi and coworkers stated that the optimal

PA stimulus for health and functional benefits among older adults should still be established [67].

Both moderate [67] and high intensity training [152] have proven to be beneficial for the older adult. Similarly, Brown et al [51] found that low intensity exercise also results in improved muscle strength and functional ability. However, Brown et al's [51] participants met three times per week, which is similar to most other intervention studies. Only a few research trials incorporated two or less exercise sessions per week [151], and found that the twice-weekly exercise did not result in any significant improvements in functional status.

Moreover, the use of specialized equipment such as treadmills or strength training machines formed part of the exercise prescription for some, while others used more versatile and accessible equipment such as thera-bands. In addition, very few of the exercise intervention incorporated seated exercises exclusively, whereas most included either gym based, or a combination of seated, standing and supine exercises [50] [51] [150] [151] [152] [153] [155] [157] [158] [159] [160]. Subsequently, there is a paucity of data on the effectiveness of an exclusively seated exercise intervention programme. Therefore, one of the objectives of this dissertation was to establish the effectiveness of a community based, low intensity seated exercise program, performed twice per week in older adults.

1.9 Aims

The aims of this dissertation were to evaluate the measurement of PA in older adults, and to characterize the relationship between physical activity and both health outcomes and functional parameters. The specific aims were:

1. The aim of the first study was to determine the test-retest reliability and criterion validity of the YPAS questionnaire, which was developed for older adults, in South Africans older than 60 years and from middle to low socio economic groups. A secondary aim of this research study was to compare the YPAS to the short IPAQ questionnaires in order to determine which instrument is best suited for and most representative of measured levels of PA in older adults.

2. Because PA has previously been associated with BMD, the aim of our second study was to identify the relationship between PA, both historical and current, and

estimated calcaneal BMD in a group of older South Africans of Mixed Racial ancestry who were of a low socio-economic status. It was hypothesized that many of the subjects would have been exposed to high levels of occupational-related physical activity throughout their lives, and that they would, therefore, be at a lower risk for osteopenia or osteoporosis.

3. Thirdly, we compared objective functional performance measures with self-reported disability from the DQ 98, ADL and IADL questionnaires. In addition, we summed the scores for each of the functional performance tests to create a functional ability index score, which we compared to the self-report measures.

4. Based on the variability in the definitions of frailty, we compared two constructs of frailty, one based on a definition from Chin A Paw[144], and one based on cognitive function, to the functional performance measures, as well as the composite functional ability index score.

5. The aim of our final study was to determine the effectiveness of a 20-week, low intensity, seated exercise programme conducted at community centres in producing beneficial changes in physical functioning, muscle strength and endurance, balance, habitual levels of physical activity, self perceived health status and blood pressure of older adults.

Table 1.1: description of Physical Activity questionnaires

Questionnaire	Sample	Time Frame	Variables	Units	Scoring method	Reference
YPAS	♀♂ 60-86 years n= 76	Usual week	Total time Energy expenditure Vigorous PA index Walking index Moving Index Standing Index Sitting Index Summary Index	Hrs/wk kcal/wk units/month units/month units/month units/month units/month total units	Time for each activity summed Time X kcal/min F X D X weight F X D X weight F X D X weight F X D X weight F X D X weight Sum of 5 indices	DiPietro et al. [19]
CHAMPs	♀♂ $\geq$ 60 years n=249	Week	Mod or > intensity PA "All" PA	Kcal/wk F/wk Kcal/wk F/wk	D X METs	Stewart et al. [162]
PASE	134 ♀ 56♂ 55-75 years	Week	Leisure (light, mod, and strenuous) Occupation Housework (light and heavy) Yard work and gardening	PA Score	Hrs/wk X item weight	Washburn et al. [163]
LTPA	♀115 (mean age 61.2 ± 6.4 years)	Lifetime PA < 17 years 18-34 years 35-50 years > 50 years	Household Occupational Exercise / sports	Hrs/wk; light, mod, heavy intensity Hrs/wk; light, mod, heavy intensity Hrs/wk; light, mod, heavy intensity	Years X F (months/yr; days/wk; time/day) Years X F (months/yr; days/wk; time/day) F (per day, week, month or year) X time	Friedenreich et al. [32]
PAR		Previous 7 days	hrs/day and kcal/kg/day	Sleep Moderate PA Hard PA Very hard PA Light PA	hrs/day X 1MET hrs/day X 4 METs hrs/day X 6 METs hrs/day X 10 METs hrs/day X 1.5 METs	Young et al. [34]
Godin Shepard		Average week	METs	Strenuous PA	No/wk X 9 METs	Rauh et al. [54]

Survey				Moderate PA Mild PA Total METs	No/wk X5 METs No/wk X 3METs Sum of strenuous, mild & moderate METs	
HLAQ	134 ♀ 39-65 years	Lifetime 14-21 yrs 22-34 yrs 35-50 yrs 51-65 yrs	MET hrs/wk	Recreational PA Total PA Mod PA Vig PA Household PA Total PA Mod PA Vig PA Lifetime PA Total PA Mod PA Vig PA	 Mod PA+ Vig PA Hrs/wk X (3.0 – 5.9) METs Hrs/wk X (>6) METs Mod PA+ Vig PA Hrs/wk X (3.0 – 5.9) METs Hrs/wk X (≥6) METs Sum of weighted average of 4 epochs	Chasen-Taber et al. [164]
SSAAQ	45♀ 44♂ 19-68 years	Previous 12 months	PA hrs/day MET hrs/day	Occupational PA Walking Leisure time PA	(Months/yr) X (4.3 wks/month) X (days/wk) X (PA hrs/day) / 365 days/year = PA hrs/day	Sobngwi et al. [165]
IPAQ – Long	14 centres in 12 countries	Usual Week or Last 7 days	METmin/wk	Occ Vig, Mod, Walking Transport Sit Walk, Cycle Yard/garden Mod, Vig Household vig Leis Vig, Mod Walking Sitting	D X F X MET intensity	Craig et al. [47]

				Weekday Weekend Total PA (sum vig, mod, walking)		
IPAQ - Short	14 centres in 12 countries	Usual Week or Last 7 dyas	METmin/wk	Vig PA Mod PA Walking Sitting Weekend Weekday	D X F X MET intensity	Craig et al. [47]
NHS II Activity Questionnaire	274 ♀ 39 ± 5 years	Usual week during the past year	METhrs/wk	Recreational PA Mod Vig Walking Flights stairs/day Inactivity Sitting Total PA/wk	D X MET equivalent (Sum of all PA)	Wolf et al. [35]
WHO-MOSPA	59♀ 108♂ mean age 36 years	Week	Time kcal/day kcal/wk	Occupation Transport Housework Leis PA	Scoring method determined by WHO	Roeykens et al. [166]

YPAS: Yale Physical Activity Survey
CHAMPS: Community Healthy Activities Model Program for Seniors
PASE: Physical activity scale for the elderly
LTPA: Lifetime Physical Activity Questionnaire
MLTPA: Minnesota Leisure Time Physical Activity Questionnaire
PAR: Stanford Seven Day Physical Activity Recall
BRFSS: Behavioural Risk Surveillance System
HLAQ: Historical Leisure Activity Questionnaire
SSAAQ: Sub-Saharan Africa Activity Questionnaire
NHS II Activity Questionnaire: Nurses Health Study II Activity Questionnaire
WHO-MOSPA: World health Organisations – MONICA Optional Study of Physical Activity
IPAQ: International Physical Activity Questionnaire
No: Number
F = Frequency

D = Duration
Mod: moderate
Vig: vigorous
Leis = leisure / ly
EE: Energy Expenditure

Table 1.2: Validity of PA questionnaires developed for older adults:

Questionnaire	Sample	Questionnaire Variable	Criterion Variable	R value	P-value	Reference
YPAS	♀♂	Total time (hrs/wk)	Caltrac counts (2.5 days)	0.08	0.71	DiPietro et al. [19]
	60-86 years	EE (kcal/wk)	Caltrac counts (2.5 days)	0.14	0.54	
	n= 25	Summary index	Caltrac counts (2.5 days)	0.37	0.09	
		Vig index	Caltrac counts (2.5 days)	0.14	0.55	
		Leis walk index	Caltrac counts (2.5 days)	0.31	0.18	
		Moving index	Caltrac counts (2.5 days)	0.13	0.59	
		Standing index	Caltrac counts (2.5 days)	-0.13	0.57	
		Sitting index	Caltrac counts (2.5 days)	0.13	0.57	
YPAS vs PAR	♀♂	Total time (hrs/wk)	Daily EE (kcal/kg/day)	0.37	0.004	Young et al. [34]
	$\geq$ 60 years	EE (kcal/wk)	Daily EE (kcal/kg/day)	0.30	0.02	
	n= 59	Summary index	Daily EE (kcal/kg/day)	0.33	0.01	
CHAMPs	62♀ 25♂	Mod PA kcal/wk	Mini logger (waist)	0.48	<0.001	Harada et al. [42]
	75 ± 6 years	Mod PA kcal/wk	Mini logger (ankle)	0.42	<0.01	
		"All" PA kcal/wk	Mini logger (waist)	0.42	<0.001	
		"All" PA kcal/wk	Mini logger (ankle)	0.36	<0.01	
PASE	62♀ 25♂	PASE Total Score	Mini logger (waist)	0.52	<0.001	Harada et al. [42]
	75 ± 6 years	PASE Total Score	Mini logger (ankle)	0.59	<0.001	
PASE	134 ♀ 56♂	PASE Total Score	VO_2 Max	0.20	<0.01	Washburn et al.[163]
	55-75 years	PASE Total Score	Resting HR	0.02	NS	
Modified Baecke	19♂	Questionnaire score	DLW	0.28	Ns	Bonnefoy et al. [167]
	73 ± 4 years		VO2 max	0.11	ns	
SDR	19♂	Mod PA	DLW	0.54	<0.05	Bonnefoy et al [167]
	73 ± 4 years	Hard PA	DLW	0.52	<0.05	
		Very hard PA	DLW	0.49	<0.05	
		Light PA	DLW	-0.43	ns	

		Total	DLW	0.51	<0.05	
MLTPA	19♂ 73 ± 4 years	Light PA	DLW	-0.24	NS	Bonnefoy et al. [167]
		Mod PA	DLW	0.19	NS	
		Heavy PA	DLW	0.47	<0.05	
		Household PA	DLW	-0.16	NS	
		Total PA	DLW	0.17	NS	

Table 1.3: Repeatability and Validity of PA questionnaires developed for younger adults

Questionnaire	Sample	Variables	Reliability		Validity			Reference
			r value	p-value		r value	p-value	
PAR	Latino ♀♂	Moderate PA	0.52	< 0.05	Caltrac Counts	0.38	< 0.05	Rauh et al.
	18 – 55 years	Hard PA	0.33	< 0.05	Caltrac Counts	0.28	< 0.05	[54]
	n=45	Very hard PA	0.86	< 0.05	Caltrac Counts	0.43	< 0.05	
		Kcal/kg/wk	0.69	< 0.05	Caltrac Counts	0.57	< 0.05	
Godin Shepard	Latino ♀♂	Strenuous PA	0.84	< 0.05	Caltrac Counts	0.34	< 0.05	Rauh et al.
Survey	18 – 55 years	Moderate PA	0.37	< 0.05	Caltrac Counts	0.13	NS	[54]
	n=45	Mild PA	0.47	< 0.05	Caltrac Counts	0.30	< 0.05	
		Total METs/wk	0.75	< 0.05	Caltrac Counts	0.35	< 0.05	
SSAAQ *	15♀ 20♂		(Women; Men)			(Women;		Sobngwi et
	19-68 years	Occ hrs/day	0.98 ; 0.91	<0.001	Polar HR monitor	Men)	< 0.01	al. [168]
	(Urban	Occ MET	0.78; 0.93	<0.001	Polar HR monitor	0.72; 0.47		
	sample)	Walking (Slow)	0.85; 0.99	<0.001	Polar HR monitor		<0.05	
		Walking (Brisk)	1.00; 0.88	<0.001	Polar HR monitor	0.56; 0.62		
		Leis hrs/day	0.94; 0.99	<0.001	Polar HR monitor		<0.05	
		Leis MET	0.94; 0.99	<0.001	Polar HR monitor	0.70; 0.44		
		Total PA EE	0.88; 0.86	<0.001	Polar HR monitor		<0.05	
					Polar HR monitor	0.63; 0.54		

IPAQ – Long	14 centres in 12 countries §	Total PA Total Sitting	0.79 0.74	CSA counts	0.46		Craig et al. [47]
IPAQ - Short	14 centres in 12 countries §	Total PA Total Sitting	0.69 0.72	CSA counts	0.37		Craig et al. [47]
WHO-MOSPA	59♀ 108♂		(ICC)		(Spearmans)		Roeykens et al. [166] ,
	mean age 36	Occ min/wk	0.77	VO_2 peak	0.21	<0.01	
	years	Transport min/wk	0.68	VO_2 peak	0.16	<0.05	
		Housework min/wk	0.55	VO_2 peak	-0.01	NS	
		Leis PA min/wk					
			0.85	VO_2 peak	0.30	<0.001	
		Occ kcal/wk					
		Transport kcal/wk	0.78	VO_2 peak	0.22	<0.01	
		Housework kcal/wk	0.68	VO_2 peak	0.17	<0.05	
		Leis PA kcal/wk	0.50	VO_2 peak	0.001	NS	
		Total PA kcal/wk					
			0.85	VO_2 peak	0.44	<0.001	
			0.81	VO_2 peak	0.39	<0.001	

Ns: Not significant
Occ: Occupation
Leis: Leisure
EE: Energy expenditure
HR: Heart rate
*: only urban sample results reported
§: Only South African Urban results reported

Table 1.4: Effectiveness of Physical Activity Interventions in Older Adults

Sample	Intervention group	Control Group	Measurements	Outcomes	Reference
Endurance Training Interventions					
20 ♂; 15 ♀ Sedentary, frail ≥ 80 years old	• 6 month Aerobic exercise: • 3-5 sessions: with instructor • Remaining sessions: on their own • Treadmill walking or stationery cycling at 60-80% of max HR. • Each session = 20-30 min • 3 days per week	None	• • Blood pressure • ADL • IADL • VO_2 peak • RER • Ex test duration	• • Sys BP decreased (p=0.01) • 33% increase in Ex test duration (p=0.01) • Vo2 peak increased 6.5% (p=0.04) • Baseline VO_2 peak and total time spent training during the 6 months were independent predictors on increased VO_2 peak at 6 months. • No significant changes in ADL and IADL ability	Vaitkevicius et al., [160]
3 ♂; 13 ♀ > 60 years old	• N=9 • Moderate intensity aerobic training. • 4 X per week • Month 1: Walking on mini trampoline, 20-30 min, @ 55% max HR. Progressed to 40 min per session, @ 60% HR max. • 3 month intervention: "running" on trampoline for 50 min per session, @ 75% max HR	N=7 Placebo control Stretching, yoga and light resistance exercises	• Abdominal adiposity • Waist circumference • Hip circumference • CT scan • OGTT • Free fatty acids • VO2 peak	• 4 months aerobic training resulted in significant improvements in glucose clearance among those who had impaired glucose tolerance at baseline. • No significant improvements in glucose tolerance was present for those with normal OGTT @ baseline. • VO2 peak increased 16% in the exercise group, but not in the CTL's	DiPietro et al. [169]

N=78 Nursing home residents	Part 1: 12 week walking program. • 5 X per week Self selected pace Part 2: • 22 week walking program	Social visits Control group 0-12 – maintain habitual levels of PA 12-22 weeks _ participated in walking program	• Walk endurance (time, distance, speed) • PA • Mobility (timed up and go, handgrip strength, Tinetti mobility assessment) • Quality of life	12 week intervention: • Intervention group improved maximal walk endurance time by 77%, maximal walking distance by 92%, compared to smaller increases in CTL (28% and 21% respectively). 22 week intervention: • Although improvements did occur in maximal walk distance, this was not significant. • There were no further significant improvements between 12 and 22 weeks.	MacRae et al. [170]
Strength training Interventions					
14 ♂; 41 ♀ Community dwelling 60-86 years	• 24 months • 3 days per week, for 60 min (0-6 months) • 2-3 days per week, for 60 min (months 6-24 months) • 11 exercises on Nautilus unit • 8-12 reps, 3 sets • 50% 1RM (set 1); 60% 1RM (set 2); 70% 1RM (set 3)	Control group maintain habitual PA levels	Testing every 6 months • Strength, reported as relative strength (1RM/BW). • Functional reach • Timed up and go • Walk up & down stairs • Floor rise • Body composition	• Strength improved significantly after 6 months in intervention group (28%)but not CTL. • The improvements in strength were maintained in intervention group until 24 months, remaining at 33 and 36% above baseline. • Ability to walk up 7 down stairs improved significantly in intervention group after 6 months, and continued to improve at 12 months. • No significant improvements in balance or co-ordination and body composition for both groups.	Brandon et al. [153]
31 ♂♀ Community dwelling Diabetics Mean age 66.1	• 24 months • 3 days per week, for 60 min (0-6 months) • 2-3 days per week, for 60		Testing every 6 months • Strength, reported as relative	• Intervention group improved significantly in trunk and lower extremity strength, and walking down stairs after 6 months, while there were	Brandon et al. [171]

years	min (months 6-24 months) • 11 exercises on Nautilus unit • 8-12 reps, 3 sets • 50% 1RM (set 1); 60% 1RM (set 2); 70% 1RM (set 3)		strength (1RM/BW). • Timed up and go • 50 foot walk • Walking up & down 8 stairs • Anthropometry	no changes in the CTL group. • Thus mobility and strength improved significantly in intervention group after 6 months, the improvements were maintained for the duration of the intervention. Strength, reported as relative strength (1RM/BW). • Functional reach	
10 ♂; 14 ♀ Moderately active, community dwelling 61-87 years	8 weeks • 3 days per week • 10 reps, 2 sets • Lower body exercises (leg extension, inner thigh press, outer thigh press, glute press, leg press, ankle press) • 0-2 weeks self selected weights. • 3-8 weeks, 75% of 1RM	Non intervention control group	• Muscle strength (1RM test every 2 weeks for each exercise part of intervention) • Maximal walking speed (25-feet) • Sit to stand test • One legged blind balance	• Improvements in strength in the intervention group ranged form 20-48%, depending on the muscle group tested. • Walking speed increased significantly at mid and post intervention compared to CTL's. • Sit to stand improved in both groups, but there were no significant between group differences. • Balance did not improve significantly in either group.	Schlicht et al. [152]
22 ♂ Community dwelling 60-75 years	16 weeks • 2 X per week • 10 reps @ 50% 1 RM • 10 reps, 3 sets @ 85-90% 1RM	Maintain habitual PA levels	• Strength • Muscle biopsies • VO_2 peak • ECG • Blood (serum lipids) • Anthropometry	• Intervention group increased muscle strength significantly after 16 weeks. • Body fat decreased significantly in the intervention group. • Increased capillarization in the intervention group, however not significant. • VO2 peak and treadmill time to exhaustion improved in intervention but not in CTL's ($p<0.05$).	Hagerman et al. [157]

14 ♂; 23 ♀ Community dwelling 60-79 years	6 weeks • 3 X per week for 45 minutes • 12-15 reps, 1 set • 9 exercises (3 = lower body and 6 = upper body)	Maintain habitual PA levels	• One arm curl test • Sit to stand test • Upper body flexibility • Lower body flexibility • 8-foot up and go test • 6 min-walk	Significant improvements in arm curl, sit to stand, upper body flexibility and the 8-foot up and go test was present in the intervention group. No significant improvements were present for the 6-minute walk test.	Cavani et al. [172]

Sample	Intervention group	Control Group	Measurements	Outcomes	Reference
74 ♂ ♀ Institutionalised ≥ 70 years	Exercise Only: 10 Weeks • 3 X per week for 45 minutes • 8 reps X 3 sets • Hip and knee extensors Nutrition Supplement: Nutition supplement comprising of 60 CHO, 23% fat and 17% protein.	Placebo: No resitance trianing, but they could particapte in three activies of their choice at a recreational therapy sercive. Nutrional placebo was a minimally nutritive (4 kcal) liquid.	ADL (Katz index) Mini mental state examination Geriatirc depression scale Anthropometry Muscle strength – 1RM Gait velocity Stair climbing power CT scans of mid thigh Habitual physical activity	Signifcant increase in muscle stregth, in the exercise group with no signicant improvements in the control group. Similarly, gait velocity improved in the exercisers but declined in the cotrol group. Stair climbing and spotaneous PA increased in the exercisers compared to the non exercisers.	Fiatarone et al. [154]
22 ♂ ♀ Institutionalized ≥ 70 years old	10 weeks • 3 days per week • 8 reps, 3 sets • High intensity (HI) group trained at 80% 1RM • Low intensity (LI) group trained at 40% 1RM	Performed the same resistance exercises as intervention groups, but with no weights except they wore empty ankle cuffs.	• Knee extensor strength and endurance • 6 minute walk • Sit to stand • Stair climbing (4 stairs) • Self reported functional difficulty	• HI group experienced significantly greater improvements in muscle strength than LI group. • Both intervention groups had greater improvements in muscle strength and endurance, and 6-minute walk distance than the CTL group. • HI and LI groups had similar	Seynnes et al. [173]

				improvements in sit to stand and stair climbing.	

Strength versus endurance training Interventions

42 ♀ 76-78 years	Strength: • 18-week progressive program. • 2 X per week, for 60 min (supervised) • 60% to 75% 1RM • 8-10 reps, 3-4 sets Endurance • 18-week progressive program. • 2 X per week, for 60 min (supervised) • Walked indoor track (2 per week) and Step aerobics (1 per week) • 50-80% HRR	Maintain habitual PA levels	• BMI • Max isometric force • Blood (Glucose, hemoglobin, erythrocyte sedimentation rate) • Blood pressure • VO_2 peak • Peak power	• Strength group increased peak power significantly compared to CTL. • Peak power per kg body weight increased in both intervention groups, no changes in CTL • Peak VO2 increased in the intervention groups, but was not significant.	Kallinen et al. [158]
439 ♂ ♀ Community dwelling ≥ 60 years Knee osteo-arthritis	Aerobic Training • 18 months (3 months facility based, 15 months home based) • 3 X per week, for 60 minutes • Walking @ 50-70% HRR Resistance Training • 18 months (3 months facility based, 15 months home based)	Health education regarding osteo-arthritis	Testing at 3, 9 and 18 months • Self report physical disability • Physical performance test (6 minute walk, timed stair climb and descent, picking up and carrying 10 pounds, getting in and out car)	• Both intervention groups had significantly better results for the 6-minute walk, lift and carry 10 pounds, and car task, and self reported disability than the health education group. • In addition the aerobic group had significantly better stair ascent and descent results than health education group. • VO2 peak increased significantly in the aerobic group.	Ettinger et al. [156]

	• 3 days per week, for 60 minutes • 12 reps, 2 sets 9 exercises (leg extension, leg curl, step up, heel raises, chest fly, upright row, military press, biceps curl, pelvic tilt)		• VO_2 peak • Strength (knee flexion and extension) • Knee x-rays • Knee pain	• Knee flexion strength improved significantly in both intervention groups, but not in the health education group. • No difference in x-rays scores were observed between the 3 groups post intervention.	
Combined Interventions					
54♂; 109♀ Community dwelling ≥ 65 years	26 weeks • Weekly structured ex class = 60 min. • Functional ex: sit to stand, weight transference, balance and co-ordination, Tai Chi • Strength ex: using own body weight, resistance bands • Aerobic ex: fast walking • Also given home ex program	N=80	• Baseline, 26 weeks, • Knee extension strength. • Ankle dorsi flexion strength • Simple reaction time • Postural sway • Balance • Sit to stand • Walking speed (6 m) • Falls frequency and severity • PASE	• Ex group improved significantly in balance, postural sway and stability tests compared to control group. • Ex group had 40% less falls than Ctl ($p<0.05$). • Ex group 34% fewer injurious falls than CTL group. • No significant improvement in strength, reaction time, walking speed, PASE and fear of falling due it the intervention.	Barnett et al. [149]
15♂; 57♀ Community dwelling > 70 years	6 months • Home based ex program. • 3 X per week • 2 sets of 8 reps • 120 min PA per week, including housework & gardening • Strength training (with	• N= 38 • 6 months • Nutrition education • Aimed to increase fruit and vege servings	• Physical performance test (PPT). • ESESE: timed balance, sit to stand, 8 foot walk • Tandem walk (20-ft) • One legged stand	• PPT and EPESE increased significantly in Ex and decreased in CTL. • Tandem walk, one-legged stand improved significantly in Ex group, but not CTL. • Max gait speed, 6 min walk performance and strength did not	Nelson et al. [150]

	ankle weights and dumbbells) • Balance training		• Max gait speed (2m) • Six minute walk • Strength: 1 RM knee extension, double leg press, chest press, la pull down • Handgrip strength	improve significantly.	
50 ♂♀ Community dwelling 65-90 years	Strength Training 16 weeks • 3 X per week • 6-8 reps, 3 sets • 50-70% 1RM for weeks 0-8 • 80% 1RM weeks 9-16 Power Training 16 weeks • 3 X per week • Same exercises as strength training. However jump squats performed instead of squats. • Weeks 0-8 same as strength training group. • Weeks 9-16, 6-8 reps, 3 sets @ 40% 1RM as fast as possible.	Maintain habitual levels of PA	• Anthropometry • Physical function (balance and co-ordination, upper body flexibility, upper body strength, endurance) • Maximal strength • Anaerobic power	• Power training group had significantly greater improvements in physical functioning than the strength or CTL groups. • No significant differences between intervention groups for maximal muscle strength and peak anaerobic power. • Strength training group were significantly stronger than the CTL group for leg press, chest press and also had more mean relative power	Miszko et al. [174]
59 ♂; 70 years or older at risk for falling	12 weeks • 3 X per week, for 90 min per session • Strength: 12 reps, 1-3 sets	Maintain habitual PA levels	• Isokinetic strength of hip, knee and ankle • Sit to stand test • 6 minute walk test • Indoor obstacle	• Knee flexion strength and endurance improved significantly in intervention group, compared to no improvement in CTL's. • Intervention group improved	Rubenstein et al. [50]

	• Endurance: cycle (5 min @ 30W, progressing to 15 min @ 80 W). Treadmill walking (5 min) Indoor walking (5-15 min) • Balance training (5-15 min)		course • One legged standing balance test • 36 item health survey • YPAS • Falls sustained during intervention period	performance in 6-minute walk, rated their health better, and increased weekly EE.	
160 ♀ Community dwelling ≥ 60 years	2X 10 week intervention programs • 2 X per week, 60 min • Strength training, • Aerobic training • Balance • Stretching • Relaxation	Maintain habitual levels of PA	• Gait (walking speed, stride duration, swing duration, stance duration) • Muscle strength (hip flexors and extensors, knee flexors and extensors, ankle dorsi flexion)	• The intervention group improved significantly for every gait and strength variable measured, compared to no improvements in the control group. • The appeared to be a dose response relationship where the percentage of improvement in gait speed, cadence, and stance duration was related to the number of exercise sessions attended. • Those with slower walking speeds at baseline, had greater improvements than those with faster walking speeds.	Lord et al. [175]
110 ♂♀ Community dwelling ≥ 75 years	3 months Balance Training (B) • 3 X per week, 45 minutes • Non-platform exercises (standing or sitting on 22-inch therapeutic ball. Exercises performed with eyes open and closed,	Education CTL's Maintain habitual levels of PA (Also participated in Tai Chi and low intensity balance training after the initial 3 month intervention)	Testing at baseline, 3 months and 9 months. • Motor and sensory balance • Functional base of support • Single leg stance time • Muscle strength	B training resulted in significant improvements in sensory balance compared to CTL's. S and B+S training groups did improve sensory balance and single leg stance time, but this was not significant when compared to CTLs. The S and B+S groups experienced improvements in muscle strength	Wolfson et al. [176]

normal or reduced foot are support, on foam or floor, with or without manual perturbations, and during maximal leaning in all directions) • Platform exercise (performed while standing on PRO BalanceMaster. Similar conditions to no platform exercises) • Gait training Strength Training (S) • 3 X per week, 45 minutes @ 70-75%1RM • Prone lying hip extension and knee flexion, side lying hip abduction performed with use of sand bags. • Resistance machines used for knee extension, ankle dorsi flexion. • Body weight was used for heel raises Balance and Strength (B+S) Training • 3 X per week, for 90 minutes. • Completed exercises from the balance and the strength training groups. • Balance exercises always performed first.	• Usual gait velocity	except for hip abduction and ankle dorsi flexion. Only the B+S group improved in gait velocity compared to the CTL group. After the 6 month maintenance (Tai Chi) phase, the B, B+S and CTL groups has reduced ability in functional base of support test. Improvements in single leg stance that occurred in B group were lost during the Tai Chi phase, while the B+S group retained their improvements. Increased muscle strength was maintained in the S and B+S groups.

CHAPTER 2:

COMPARISON OF TWO METHODS OF MEASURING PHYSICAL ACTIVITY IN SOUTH AFRICAN OLDER ADULTS

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2.1. Introduction

Morbidity from non-communicable diseases such as coronary artery disease and hypertension accounts for 37% of all deaths in South Africa between the ages of 35-64 years [6]. The majority of South Africans have at least one modifiable risk factor for chronic diseases [177]. There is consistent evidence that regular PA has been associated with an overall reduction in morbidity and mortality [56] in developed countries. However, there are no current data concerning physical inactivity prevalence amongst South Africans.

Despite evidence that PA can preserve mobility in older adults, there is a trend for activity levels to decline with increasing age. The decline in activity levels is more pronounced in women, low-income groups and in persons with low education levels [24;37;37]. In a recent cross sectional study in a peri urban community in the Western Cape, South Africa, "vulnerable groups" reporting the lowest levels of PA were young women (15-24 years) and men and women over the age of 55 years [87]. Therefore, the measurement of the prevalence of inactivity has become increasingly important for public health purposes.

However, some evidence suggests that the observed decline in PA in older adults may be related to, in part, methodological errors or bias in reporting or recall of PA [19]. Therefore, the choice of instrument, the design of questionnaires and the manner in which the data are collected and recorded, influences the determination of energy expenditure [53]. Many PA surveys have been designed for younger populations and may not accurately represent PA patterns in older adults [19]. In addition, few studies have evaluated the validity of PA questionnaires for this age group [19]36} [34].

DiPietro and colleagues developed and validated the Yale Physical Activity Survey (YPAS) for older adults [19]. The questionnaire assesses PA in five domains, namely, household, yard work, care giving, exercise and recreational energy expenditure [19]. The YPAS demonstrated adequate reliability and validity in a North American population, however, the researchers recommended that it be tested in a variety of populations to establish its external validity.

In addition, a working group for the World Health Organisation (WHO), together with the Centre for Disease Control (CDC) developed an International Physical Activity Questionnaire (IPAQ) designed to enable countries to assess physical activity in a comparable manner and to be used for cross-cultural surveillance [47]. The questionnaire was developed primarily for younger adults (<60 years old), and the validity and reliability in older populations has yet to be determined [47].

Therefore, the aim of this study was to measure the test-retest reliability and criterion validity of t short form of the IPAQ questionnaire in South Africans older than 60 years. A secondary aim of th research study was to compare the short IPAQ and YPAS questionnaires to determine whi instrument is best suited for and most representative of measured levels of physical activity in old adults.

2.2. Methods:

2.2.1. Subjects:

A convenience sample of 122 subjects older than 60 years (52 men and 70 women) was dra from memberships at senior citizen luncheon clubs and also by "word of mouth". An exclusi criterion was a change in habitual physical activity patterns three months prior to or during t research testing, for example, if a participant was recently hospitalised. The Ethics and Resear committee of the Faculty of Health Sciences at the University of Cape Town approved this stu and informed written consent was obtained from all subjects.

2.2.2. Anthropometric Measurements:

Height was measured to the nearest cm in subjects without their shoes, using a wall-mounted ta measure. Body mass was measured using a portable calibrated scale and recorded to the neare 0.5 kg. BMI was calculated as body mass (kg) divided by height (m) squared (kg/m^2).

Waist circumference was recorded at the level of the umbilicus and hip circumference wa measured at the largest diameter below the umbilicus or maximum circumference over th buttocks. Waist-to-hip ratio was calculated as waist divided by hip circumference.

A Harpenden caliper was used to measure skinfold thickness at four sites, sub-scapular, supra-ilia triceps and biceps. Percentage body fat was estimated using the Durnin and Womersley equatio [178].

2.2.3. Questionnaires:

Trained field workers administered the questionnaires, either at the senior centre, or at the participant's home. The order of administration of the short IPAQ and YPAS questionnaires was initially randomised, and this order was maintained for the second interview.

2.2.3.1. Yale Physical Activity Survey:

Habitual PA was measured using Part 1 of the YPAS in which participants were asked to estimate the amount of time spent during the week prior to the first interview in various activities including household, yard work, care giving, recreation and exercise. Each activity was assigned an intensity code (kcal) as described by DiPietro [19], and subsequently multiplied by the time spent to calculate kcal/week. Individual weekly energy expenditure was calculated for four activity domains: household chores, gardening, care-giving and recreation, which were summed to estimate total weekly energy expenditure.

2.2.3.2. Short Version of International Physical Activity Questionnaire (IPAQ):

The WHO-CDC International working group [47] developed a long and short version of the IPAQ questionnaire. These interviewer-administered questionnaires quantify the amount of energy expended for vigorous and moderate activity for one week, based on the frequency, intensity and duration of the activities.

The short version was administered to our study participants and they were asked to recall the intensity and duration of activities, inclusive of occupation, transport, leisure, and household activities, performed during a usual week. Times were only recorded if the activity lasted for 10 minutes or more. In addition, the amount of time spent sitting during a week and weekend day, was recorded. Subjects were asked to grade the intensity of walking as slow, moderate or vigorous pace. Energy expenditure was derived by multiplying the frequency and duration of the reported activities by an estimated MET value [179] in order to report MET min /wk for vigorous, moderate and walking activities. Vigorous activities were assigned a MET value of 8, moderate activities 4 METS. Vigorous walking equalled 5 METS, moderate walking 3.3 METS and slow walking 2.5 METS.

2.2.4. CSA Monitor:

Each participant wore a small Computer Science and Applications (CSA) activity monitor (Mo 7162, Shalimar, FL) for seven consecutive days to measure bodily accelerations in a uniaxial pla The acceleration signal is filtered by an analog bypass and digitalised by an 8-bit analog to dig converters (A/D) at 10 samples per second (CSA manual). The A/D converter measures magnitude of the accelerations, which is summed over a set time period or epoch. The monitors our study were programmed to record data in 60-second time epochs. The counts recorded in ea epoch represent the quantity and magnitude of accelerations.

Participants were instructed to wear the monitor from the time they rose from bed in the morni until the time they retired each night, except during activities such as bathing, showering swimming. The monitor was attached to a belt around the waist and worn on the right anterior h and the importance of correct positioning was emphasised to each participant. In additi participants were asked to maintain their normal weekly activity patterns while wearing the moni CSA monitors were retrieved from the participants after seven days and downloaded onto computer using a reader interface unit. A minimum of 10 hours per day of data was needed analysis. The minutes per day spent in moderate, vigorous and very vigorous activity we calculated, as well as continuous periods of activity, total registered time, total counts and cou per registered time.

2.2.5. Reliability:

Test-retest reliability was determined by comparing the estimates for energy expenditure, for bo questionnaires, administered to the participants on two occasions separated by a minimum of thr days and a maximum of five days.

2.2.6. Validity:

2.2.6.1. Concurrent validity:

The YPAS and short version of the IPAQ were compared, as a measure of concurrent validit Each questionnaire was administered on two occasions. The order of the administration of the tw questionnaires was randomised between participants, and was maintained at the second visit fo each participant. Energy expenditure estimates measured in the YPAS were, kcal/week an hours/week spent for household, yard work, care giving, recreation, and exercise related activities. In addition, total (sum of each domain) kcal/week and hours/week were calculated. For the short IPAQ, vigorous MET min/wk, moderate MET min/wk, walking MET min/wk and sitting MET min/wk were estimated.

2.2.6.2. Criterion validity

Energy expenditure estimates from the YPAS and IPAQ questionnaires were compared to data obtained from the CSA monitor. Data obtained from the CSA monitor included time (calculated from CSA counts) spent in vigorous and moderate activity, total CSA counts and the number of counts recorded during registered time (the time during which the subject wore the monitor). The Freedson et al. [66] equation was used to determine the cut off points to calculate time spent in moderate, vigorous and very vigorous activities. Counts > more than 1952/min and ≤ 5724/min were classified as moderate activity while vigorous activity was classified as counts > 5725 per epoch (1 minute).

2.2.7. Statistical analysis:

STATISTICA software package was used for all the analyses (Stasoft, Inc. 184-199, Tulsa OK, USA). Descriptive statistics were performed for the total sample and for the men and women separately. Independent t-tests (based on first visit) were used to detect significant differences between the men and women. Mean values presented in the results are based on those obtained from the first administration of the questionnaires.

Spearman's rank order correlation coefficients (r) were used to determine concurrent validity (YPAS vs. IPAQ) and criterion validity (YPAS and IPAQ vs. CSA monitor) and test–retest reliability (first vs. second administration). Kappa statistics were also used to calculate concurrent validly, after the total weekly energy expenditure for the IPAQ and YPAS was divided into quartiles. Criterion validity results are those obtained from the first administration of the questionnaire, as it was similar to that obtained from the second visit.

Limits of agreement between visit one and two of the YPAS and short IPAQ were calculated using the Altman and Bland [180] technique. A bias table was created, where the bias is the difference between the mean values of the two tests. The 95% limits of agreement were calculated as the mean ± 1.96 X standard deviation [180]. The level of significance for all statistical analyses was alpha < 0.05.

2.3. Results

2.3.1. Subject Characteristics:

The demographic characteristics of the research participants are presented in Table 2.1. The men were older (mean age 68 ± 5 years and 66 ± 6 years, respectively; p=0.031). In addition, men had a higher level of education than the women, 10.7 ± 5.1 years and 8.2 ± 2.8 years of education, respectively (p<0.001).

2.3.2. Energy expenditure in men and women

The mean weekly energy expenditure was similar for men and women (3574 ±2877 kcal/wk and 3670 ± 3633kcal/wk, respectively) as measured by the YPAS questionnaire (Figure 2.1). However, women had higher energy expenditure for household work than men, 2182 kcal/wk ± 1772 vs. 1275 ± 766 kcal/wk, p =0.0008). The men had higher yard work-related energy expenditure, (659 ± 1130 kcal/wk vs. 144 ± 311 kcal, p=0.0004). Exercise and recreation-related energy expenditure were similar for men and women.

Total mean weekly energy expenditure as measured by the IPAQ was higher for men than women, (5396 ± 2624 MET min/wk vs. 4620 ± 1628 MET min/wk, p=0.046, Figure 2.2). Both men and women spent most of their time sitting, with small amounts of vigorous activity. Men expended more energy in moderate intensity activities compared to women (690 ± 1104 MET min/wk and 203 ± 263 MET min/wk, respectively; p=0.005).

2.3.3. Reliability of YPAS

The test-retest reliabilities of the YPAS and IPAQ questionnaires are presented in Tables 2.2 and 2.3 respectively. The YPAS questionnaire was more repeatable for women than men, lowest r=0.59 (p<0.001) for recreation-related energy expenditure highest r=0.99 (p<0.001) for care giving activities). For men, yard work and care giving activities were most repeatable, r=0.80 (p<0.001) and 0.81 ($p<0.001$), respectively, while household energy expenditure was the least repeatable, $r=0.44$ ($p<0.001$).

In men, the limits of agreement showed a consistent pattern for yard work, exercise and total weekly energy expenditure, with subjects tending to report higher levels of energy expenditure at the first visit. Conversely, reported housework and care giving energy expenditure were higher at the second visit. The limits of agreement were wide for these domains (household: -1903.8 to 2107.32 kcal/wk, yard work: -1502.0 to 1489.3 kcal/wk, care giving –1986.2 to 2086.58 kcal/wk, and exercise 3466.26 to 2772.1 kcal/wk). Recreational energy expenditure was more consistently reported between the two visits for the men. Men generally over-reported total weekly energy expenditure at the first visit (Table 2.6).

Similarly, the women reported higher levels of energy expenditure at the first visit. The limits of agreement for women were narrower compared to the men. The limits of agreement were narrowest for yard work, care giving, and recreation related energy expenditure (Table 2.6).

2.3.4. Reliability of short IPAQ

For the short IPAQ, walking and sitting activities were best recalled for both the men and women (Table 2.3). Both vigorous and moderate activities were more repeatable for the women compared to the men. The IPAQ showed similar levels of repeatability as the YPAS for both the men and women. Total weekly energy expenditure was similar in the men and women when using the YPAS (Table 2.2) and the short IPAQ (Table 2.3).

The limits of agreement were wide for vigorous activity (-4606 to 5279 MET min/wk), moderate activity (-2248.9 to 1857 MET min/wk) and for walking (-3475.4 to 4164.9 MET min/wk) for the men. Reported total weekly energy expenditure (Table 6) tended to be higher at the second visit.

For the women, the limits of agreement for vigorous (-1339.86 to 1438 MET min/wk), moderate (-673.9 to 654.6 MET min/wk) and total weekly energy expenditure (-3669.8 to 4364.0 MET min /wk) were narrower than for the men (Table 2.6). The women tended to report higher energy expenditures on the first administration of the IPAQ. The limits of agreement were greater for walking and sitting activities compared to the men and also that of vigorous and moderate activity. Sitting was less consistently reported in women than the men, however, vigorous and moderate activities were more consistently reported between the two visits compared to the men.

2.3.5. *Concurrent validity (IPAQ versus YPAS)*

The energy expenditure results, comparing both instruments, on visit two, were significantly correlated (r=0.53; p=0.001 and r=0.30; p=0.017, for men and women, respectively). Furthermore, moderate and walking METmin/wk from the IPAQ were significantly associated with the exercise, recreation and total weekly energy expenditure domains of the YPAS (r = 0.29-0.52; p<0.03) (data not shown) for the men. Among the women, moderate and walking METmin/wk were significantly correlated to the YPAS exercise domain (r=0.25 and r = 0.32; p<0.03, respectively). The Kappa result, however, - for both the men and women was poor (0.03 for both) for the first visit and improved only slightly when comparing the second test administrations (0.10 and0.12, respectively).

2.3.6. *Criterion validity of YPAS*

Similarly, the relationship between the YPAS and CSA monitor was stronger for the men than the women (Table 2.4). For the men, the strongest association was found between total weekly and exercise energy expenditure and total CSA counts (r=0.54 for both; p<0.001). Time spent in moderate activities measured with the CSA monitors was significantly associated with house-work (r=0.31; p=0.043), exercise (r=0.40; p=0.008) and total weekly energy expenditure (r=0.42; p=0.006) for the men. Exercise energy expenditure and time spent in moderate activities as measured by the CSA monitor had the strongest relationship for women, (r=0.29, p=0.021), compared to the other domains of activity measured by the YPAS.

2.3.7. *Criterion validity of short IPAQ*

Energy expenditure and motion counts from the CSA monitors correlated with specific domains of activity (IPAQ), but not with total energy expenditure (MET min/wk), for both men and women (Table 2.5). Motion counts were significantly correlated to vigorous expenditure as measured by the short IPAQ in men. Vigorous MET min/wk and moderate MET min/wk were not significantly correlated to any of the CSA monitor parameters for the women. The strongest relationship was found for walking MET min/wk and total CSA counts for both the men and women (r=0.57;p<0.001 and r=0.42;p<0.001, respectively). Walking MET min/wk were significantly associated with moderate CSA counts and counts/registered time for both men and women, (r=0.56, p<0.001, r=0.55, p<0.001, r=0.32, p=0.011, r=0.39, p=0.002), respectively. Sitting MET min/wk were negatively and significantly associated with continuous CSA time and total CSA counts for both men and women, (r= -0.39, p=0.01); r= -0.40, p=0.001, r= -0.32, p=0.011, r= -0.35, p=0.005), respectively. For men, sitting MET min and time spent in moderate activities measured by the CSA monitor, were also negatively associated (r= -0.45, p=0.003).

2.4. Discussion

Levels of PA tend to decline with increasing age despite the evidence that it can improve health and functional status. One of the main methods for assessing PA in epidemiological studies is by means of questionnaires, however, there are few reliability and validity studies conducted with older adults, particularly women. Therefore, the current study aimed to compare two PA questionnaires, the YPAS and short IPAQ, in an older adult population comprising of both men and women, drawn largely from a socio-economically disadvantaged community.

The first important finding of this study was that both the YPAS and short IPAQ performed similarly in terms of reliability, particularly for total weekly energy expenditure, in comparison to other studies [19;19;34;34;42;47;47]. The YPAS and IPAQ had similar test-retest reliability for total weekly energy expenditure, with better correlations for the women than men. The reliability of total weekly energy expenditure measured by the YPAS was weaker for the men in the present study, when compared to the results obtained by Harada et al. 2001 [42], who used the CHAMPS questionnaire. The CHAMPS instrument was designed to measure the effects of an intervention on physical activities, including moderate and vigorous intensity activities [42], while the YPAS captures predominantly low intensity activities that are performed more frequently by older adults.

Similarly, total weekly expenditure (YPAS) repeatability for men were comparable to that obtained by DiPietro et al. [19] (r= 0.57; p< 0.001), and was stronger for the women (r= 0.62; p<0.001 vs. 0.58; p<0.001). Care giving in the YPAS was best recalled for both men and women, and this may be related, in part, to the small proportion of our sample that engaged in care giving activities. This is supported by Booth and co workers (1996) [55], who stated that if a large proportion of the study sample reported no participation in an activity for the test and retest measurements, the reliability measure is likely to be inflated.

For the short IPAQ, the reliability coefficient for total weekly energy expenditure was similar to that obtained from a sample young South Africans and Guatemalans (urban and peri-urban sample combined) [47]. However, when comparing our sample to the urban South African or Guatemalan

[59], found that the CSA monitor had stronger correlations with total energy expenditure recorded in an activity diary ($r=0.54; p<0.001$) and the Stanford 7 day recall questionnaire ($r=0.33$; $p>0.05$), than with the specific activity domains ($r=0.09$ to 0.65). In addition, Jacobs et al. [31] found weaker associations between the MTLPAQ and the Caltrac motion sensor among 20-59 year olds where the associations between light, moderate and heavy activity and the motion sensor were low $r=0.07$, 0.22 and 0.16, respectively. The MLTPAQ assesses activity over the past 12 months, whereas the IPAQ assesses one week's activity. Thus, the ability to recall PA and intensity is likely to be more accurate in our subjects since they were only required to remember physical activity for a usual week.

For the YPAS, the correlation coefficient between total CSA counts and total energy expenditure was more robust than that obtained in Sirad et al. [59] who compared the CSA monitor and the Stanford Seven Day recall in 10 women, mean age 25 years. Furthermore, the correlation between the YPAS and CSA monitor in the current study yielded stronger results than that obtained by DiPietro et al. [19] in which total weekly kcal was not significantly associated with the Caltrac motion sensor ($r=0.14$; $p=0.54$). The difference between our results and that of DiPietro [19] may in part be due a longer period of data collection (minimum of 5 days vs. 2.5 days).

In summary, one of the main strengths of this research study was that the sample was drawn from a population comprised largely of older women, from a working class community. These are population groups that are often under-represented in reliability and validity studies [34]. The YPAS includes activities that are common among older adults, particularly light intensity activity, which is often excluded from other physical activities assessment tools [34]. In addition, the YPAS has previously been shown to detect changes in activity after a PA intervention [34;42]. The short IPAQ provides an estimate of PA that can be compared globally, in both developed and developing countries [47]. We have shown that the YPAS and short IPAQ have comparable results for reliability and criterion validity in the older adults.

These data suggest that both the YPAS and short IPAQ instruments provide reasonably reliable estimates of PA in older adults in this community. The choice of instrument, therefore, may depend on the desired outcome or use of the data generated.

The quantification of PA using validated and reliable tools enables researchers to determine the association between PA and health outcomes; particularly in epidemiological surveys were direct measures of energy expenditure ore impractical and expensive. Our findings have shown that both instruments could be used to measure current levels of PA in the older adult population. However, the YPAS has considerable appeal in our population, since the activities were easily recalled and it allows for identification of the most common domains of habitual PA. As a result, we have chosen this instrument to quantify PA in our subsequent investigations.

Table 2.1: Demographics of men and women participating in the study. Mean ± standard deviation

	Men (n=52)	Women (n=70)
Age (years)	68 ± 5.4	66 ± 5.8
Education (years)	10.7 ± 5.0	8.2 ± 2.8
Stature (cm)	171.6 ± 8.4	155.8 ± 6.4
Mass (kg)	77.4 ± 13.4	73 ± 15.6

Table 2.2: Spearmans' Rank order correlation for reliability of the YPAS

	Men (n=52)		Women (n=70)	
	r	p value	r	p value
Household EE	0.44	0.0009	0.64	0.0000
Yard work	0.80	0.0000	0.84	0.0000
Care giving	0.81	0.0000	0.99	0.0000
Exercise	0.64	0.0000	0.74	0.0000
Recreation	0.45	0.0007	0.59	0.0000
Total Week EE	0.57	0.0000	0.62	0.0000

Table 2.3: Spearman's Rank order correlations for reliability of the short IPAQ.

	Men (n=52)		Women (n=70)	
	r	p value	r	p value
Vigorous METmin	0.29	0.0480	0.46	0.0001
Moderate METmin	0.36	0.0135	0.44	0.0002
Walking METmin	0.76	0.0000	0.75	0.0000
Total Sitting METhrs	0.76	0.0000	0.77	0.0000
Total Weekly EE METmin	0.54	0.0001	0.60	0.0000

Table 2.4: Spearman's rank order correlations for criterion validity – YPAS vs. CSA monitor data for men and women

YPAS (kcal/wk)	CSA Monitor	Men (n=42) r	Men (n=42) p-value	Women (n=61) r	Women (n=61) p-value
Work	Time moderate	0.31	0.0432		NS
Work	Cont Time	0.35	0.0237		NS
Exercise	Time moderate	0.40	0.0083	0.29	0.0213
Exercise	Time High	0.39	0.0090	0.27	0.0249
Exercise	Cont time	0.34	0.0267		NS
Exercise	Total Counts	0.54	0.0002	0.28	0.0261
Recreation	Time Moderate		NS	-0.26	0.0446
YPAS TTL EE	Time moderate	0.42	0.0059		NS
YPAS TTL EE	Cont Time	0.42	0.0058	-0.29	0.0233
YPAS TTL EE	Total counts	0.54	0.0002		NS

Table 2.5: Spearman's rank order correlations for criterion validity – short IPAQ vs. CSA monitor data for men and women

IPAQ(Met min)	CSA Monitor	Men (n=42) r	Men (n=42) p-value	Women (n=61) r	Women (n=61) p-value
Vigorous	High CSA counts	0.43	0.05	0.05	NS
Moderate	Time moderate	0.31	0.004	-0.09	NS
Moderate	Total CSA counts	0.37	0.017	0.08	NS
Walking	Time moderate	0.56	0.0001	0.32	0.011
Walking	Total CSA counts	0.57	0.00007	0.42	0.0006
Sitting	Time moderate	-0.45	0.003	-0.22	NS
Sitting	Continuous Time	-0.39	0.01	-0.32	0.011
Weekend Sitting	Total CSA count	-0.40	0.001	-0.35	0.005

Table 2.6: Bias of the estimates and random variation for the first and second administration of the IPAQ and YPAS questionnaires

		Mean	Standard Deviation	95% limits of agreement	
Men	**Short IPAQ**			**(upper)**	**(lower)**
	Vigorous METmin/wk	336.15	2471.48	-4606.80	5279.10
	Moderate METmin/wk	-195.77	1026.55	-2248.87	1857.34
	Walking METmin/wk	344.7	1910.12	-3475.44	4164.93
	Total IPAQ METmin/wk	324.58	3767.43	-7210.28	7859.43
	YPAS				
	Work	101.76	1002.78	-1903.80	2107.32
	Yard work	-6.35	747.66	-1502.00	1489.31
	Care giving	50.19	1018.20	-1986.20	2086.58
	Exercise	-347.08	1559.59	-3466.26	2772.11
	Recreation	-117.41	875.98	-1869.38	1634.55
	Total YPAS kcal/wk	-572.60	2499.88	-5572.37	4427.17
Women	**Short IPAQ**				
	Vigorous METmin/wk	49.26	694.56	-1339.86	1438.37
	Moderate METmin/wk	-9.66	332.12	-673.9	654.59
	Walking METmin/wk	110.02	1029.12	-1948.21	2168.25
	Total IPAQ METmin/wk	347.14	2008.44	-3669.75	4364.02
	YPAS				
	Work	-260.66	4152.65	-8565.96	8044.64
	Yard work	-30.39	270.16	-570.71	509.94
	Care giving	3.5	21.79	-40.08	47.08
	Exercise	-320.66	2294.17	-4908.99	4267.69
	Recreation	89.16	1024.72	-1960.28	2138.61
	Total YPAS kcal/wk	-1.22	2703.50	-5408.22	5405.71

Figure 2.1: Weekly energy expenditure measured by YPAS

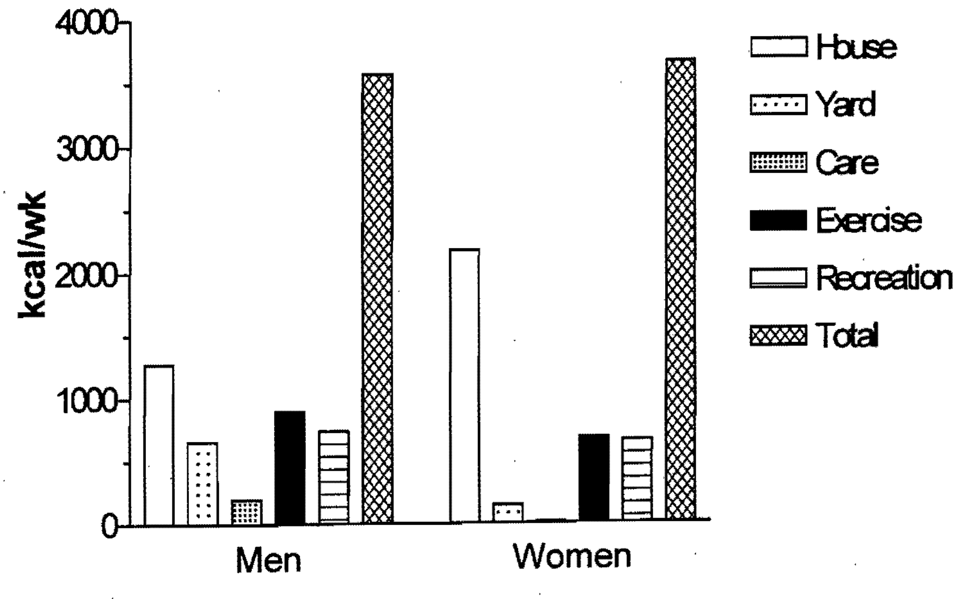
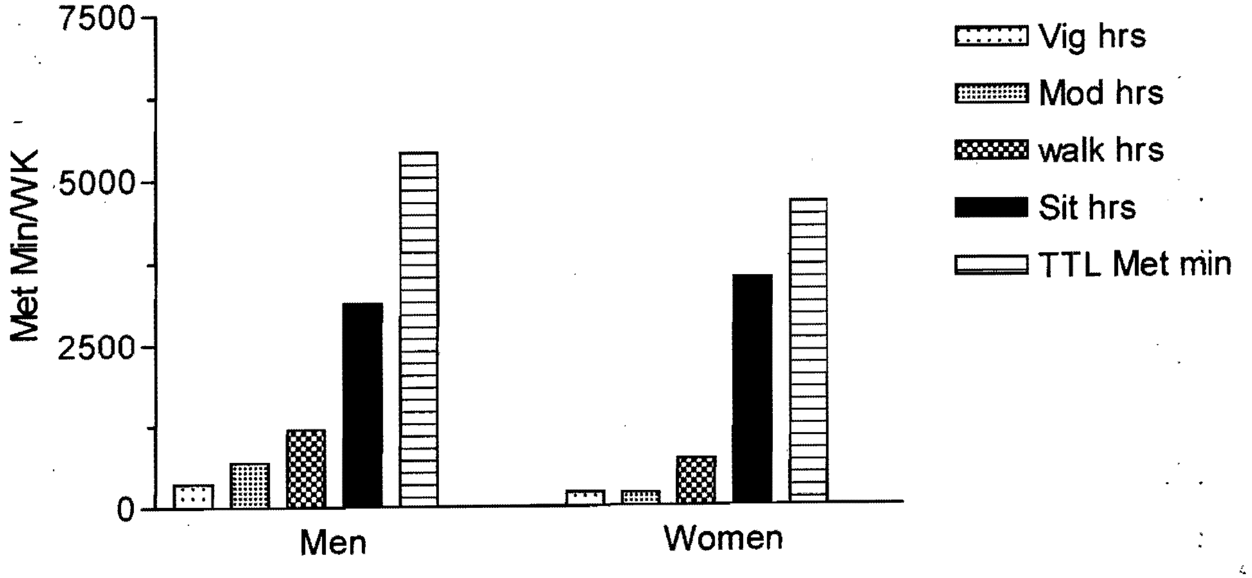


Figure 2.2: Weekly energy expenditure measured by IPAQ



CHAPTER 3:

LIFETIME PHYSICAL ACTIVITY AND DETERMINANTS OF ESTIMATED BONE MINERAL DENSITY USING CALCANEAL ULTRASOUND IN OLDER SOUTH AFRICAN ADULTS

Accepted for publication in part;
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3.1. Introduction

Regular PA has been associated with the prevention and treatment of chronic diseases of lifestyle [48]. However, there is a paucity of data from older adults in Sub-Saharan Africa, investigating the association between PA and health. The reliability and validity of the questionnaires investigated in Chapter 2, have now been established in our population group. As a result, we are able to investigate the relationship between habitual PA and health in older adults from low socio economic and educational groups.

In a previous study in older adults from a working class community, lifetime PA was associated with systolic blood pressure ($p<0.05$) Charlton et al. [20]. There is some evidence that lifetime PA, in particular, occupational and household PA, may be important determinants of Bone Mineral Density (BMD) in older adults women [111]. This is relevant as osteoporosis is a significant source of morbidity and mortality in older adults from developed countries [67]. However, there is a paucity of data concerning lifestyle factors and bone health in older adults from disadvantaged communities. Therefore this study was designed to investigate the relationship between both lifetime and current PA in older South Africans.

Osteoporosis is a disease characterized by low bone mass and the deterioration of bone tissue which ultimately leads to increased bone fragility and a consequent increase in fracture risk [184]. Genant et al. estimates that hip fractures will exceed 6 million annually by 2050, worldwide, and that 75% of these fractures will occur in developing countries [185].

Peak bone mass is achieved between the ages of 25 and 30 years and then reduces at a rate of approximately 1% per year [99]. Women experience a decline in estrogen as they approach menopause and this accelerates the rate of bone loss [186]. Therefore, low bone mass in the older adult may be due to age-related bone loss, and may be compounded by a low peak bone mass achieved between the ages of 25 and 30 years.

Physical activity has been shown to improve peak bone mass, and therefore, the older person who has been exposed to a high level of lifetime PA may show an attenuated rate of bone loss compared to less active individuals of the same age [81]. Kriska et al. concluded that mechanical loading, associated with physical activity prior to the mid-thirties, resulted in increased bone area and peak bone mass amongst a group of older North American women (mean age 58 years). Furthermore, current levels of PA were associated with the maintenance of bone mass in these older women [81].

Although the association between current and, in some cases, lifetime PA has been established in developed countries, and largely in Caucasian populations [81;110;110;187;187;188;188], there is a paucity of data in under-developed countries and in other ethnic groups. In addition, most research has focused on leisure time PA. There are no examples of studies in which occupational activity early in life which is largely manual or unskilled labor, has been compared to bone health parameters.

In the present study, we measured occupational, household and leisure-time related activities in order to quantify historical and current levels of PA in a non-Caucasian population from a poor fishing village. Furthermore, most of the subjects for the present study had relatively high levels of occupational physical activity, as they had worked or were working as fisherman or packers for the fishing industry.

Therefore, the aim of this study was to identify the relationship between PA, both historical and current, and estimated calcaneal BMD in a group of older South Africans of Mixed Racial Ancestry who were of a low socio-economic status. It was hypothesized that many of the subjects would have been exposed to high levels of occupational-related physical activity throughout their lives, and that they would, therefore, be at a lower risk for osteopenia or osteoporosis.

3.2. Methods

3.2.1. Subjects

One hundred and fifty nine residents aged 55 years and older (47 men and 105 women), who were from an ethnic group described as Mixed Racial Ancestry (Coloured), residing in one of two peri-urban fishing villages along the South West Coast of South Africa participated in the research study. The Mixed Racial Ancestry population is of African-European-Malay ancestry, and has historically been socio-politically and socio-economically disadvantaged as a result of the Apartheid legislation. Off shore and in-shore trawling and pelagic fishing are practiced in both villages and most of the participants had previously been employed in the local fish factories, were fishermen, or in the case of women, were domestic workers. A list of names and addresses was obtained from the local primary health care clinic, known as "day hospitals' or "community health centers". One of the main functions of these health care clinics is to dispense medications and provide basic examinations, particularly for those with chronic conditions such as hypertension, diabetes and coronary artery diseases. A convenience sample was drawn using the address list and also from word of mouth referral.

The fracture history of the participants was not known, as it is highly unlikely that the participants were attending the health care center for treatment resulting from a fall or fracture. Participants visited community centers, located in each village, on two successive days during which time questionnaires were administered and measurements of calcaneal ultrasound and anthropometry were taken. The Ethics and Research committee of the Faculty of Health Sciences at the University of Cape Town approved this study. Informed written consent was obtained from all subjects.

3.2.2. Measurements

3.2.2.1. Questionnaires

Trained interviewers administered a questionnaire pertaining to socio-demographic variables, including age, income and housing density.

3.2.2.2. Physical activity levels

Current habitual PA levels were assessed using an interviewer-administered version of the Yale Physical Activity Survey (YPAS) for older adults [19], as described in chapter 2, section 2.2.3.1. .

Lifetime levels of physical activity (LTPA) were assessed using a modified version of the questionnaire developed by Kriska et al. [81]. Subjects were asked to describe the mode of activity and to quantify the average time spent per week in leisure, work and household-related activities for 5 age epochs (14-21; 22- 34; 35- 49; 50-64 and 65+ years). Energy expenditure for each domain was calculated as metabolic equivalents (MET hrs/week) [189]. Each activity was assigned a MET value based on the Current Compendium of Physical Activities [189]. (One MET represents the approximate rate of oxygen consumption of a seated adult at rest, or about 3.5ml/min/kg, which equates to an energy cost of about 4.2

kJ/kg/hr [1 kcal/kg/hr]). For the purpose of statistical analysis, activities requiring less than 3 METs were classified as low intensity, and those requiring 3-6 METS or more as moderate intensity, and total energy expenditure as low + moderate intensity (< 3 METs + 3-6 METs).

The average participation for each activity performed during each age epoch was calculated as follows;

(yrs participated in activity) X (months/yr) X (hours / week) ÷ (no. yrs in epoch) ÷ (52 wk/yr) = hrs/week [80]

The total number of MET hrs/week was calculated for each epoch. In addition, total lifetime energy expenditure was calculated by summing the MET hrs/week for epochs one to four. Epoch five was excluded from total lifetime energy expenditure calculations because 56% of the subjects were between the ages of 55 and 64 years.

3.2.2.3. Bone strain units

Each activity recorded in the Lifetime Physical Activity Questionnaire was also allocated a peak bone strain score based on estimated ground reaction forces [190]. Activities that included jumping were allocated a peak strain score of 5; those that included sprinting and turning actions were rated as 3; weight bearing activities were rated as 2; and all other activities were rated as 1. Examples of activities rated as five included netball, those rated as three included rugby and soccer. Occupational activities for those who were fisherman or packers and domestic workers, received a bone strain rating of two.

The bone strain for each activity in each age epoch was calculated as follows;

(Strain) X (hrs/wk) = strain hrs/week for the epoch.

The lifetime bone strain units were calculated as the sum of the total strain units from epochs one to four.

3.2.2.4. Habitual dietary intake

Trained interviewers administered a semi-quantitative food frequency questionnaire (FFQ). The FFQ comprised 175 food and drink items (including alcohol consumption), and considered only food and drinks consumed during the previous two weeks, as well as the frequency of consumption and the quantity consumed at a time. Standard household measuring utensils, rulers and foam food models were used to quantify food portion sizes. The reported fortnightly food intake was quantified using the National Research Institute for Nutritional Diseases' Food Quantities Manual [191] and averaged for 14 days to yield daily food intake in grams. Average daily nutrient intake was calculated using the Foodfinder computer package, based on the 1991 food composition database of the South African Medical Research Council [192].

3.2.2.5. Estimated Bone Mineral Density

Bone density was estimated using a quantitative ultrasound attenuation technique (SAHARA,® Hologic; Waltham, Massachusetts, USA) of the calcaneus. The coefficients of variation for the Sahara,® Hologic has been previously reported as 3.0% for estimated heel BMD, 2.6% for QUI, 0.22% for SOS and 3.7% for BUA [101]. The machine was calibrated each morning, using the phantom. A single QUS measure was taken for each participant. Participants were seated and asked to remove their shoes and socks. The heel was placed between two transducers and a sound wave passed from one transducer to the other.

The SAHARA,® (Hologic) measures three parameters, BUA, SOS, Quantitative Ultrasound Index (QUI). BUA is the blocking of sound waves as they pass from the transmitting transducer to the receiver transducer [93]. Osteoporotic bone has a lower BUA and SOS than healthy bone. The BUA and SOS measurements were then combined to determine QUI [93], which is linearly rescaled to calculate estimated heel BMD, in g/cm^2. Estimated BMD obtained from the SAHARA,® in Caucasian populations is highly correlated to DEXA heel BMD, r=0.85 [193].

T-score, which is the difference between the individual's score and the mean results for a young adult population, is also one of the outputs of the SAHARA,®, and was recorded. The WHO classifies an individual with a T-score between -1 standard deviations (SD) and less than -2.5 SD as osteopenic, while a T-score of more than -2.5 SD is regarded as indicative of osteoporosis [194]. This classification is based on the measurement technique and the site measured. The classification of subjects based on WHO [194] guidelines may however differ between results obtained from the DEXA and calcaneal ultrasound.

3.2.2.6. Anthropometrical Measurements:

A single trained investigator measured height and weight, and body mass index (BMI) was calculated as weight (kg/m^2). Waist circumference was recorded at the level of the umbilicus and hip circumference was measured at the largest diameter below the umbilicus or maximum circumference over the buttocks. Waist-to-hip ratio was calculated.

3.2.2.7. Sit to Stand

Lower body muscle strength was assessed using the sit to stand test, in which the maximum number of sit-to-stand repetitions that could be completed by a subject in 10 seconds was recorded [124;134;134]. The sit to stand test was conducted on the same chair, which was a standard height for all participants. Subjects started from the seated position and were instructed to keep their arms crossed over the chest for each repetition. Each participant was verbally encouraged to stand up and sit down as fast as possible for the duration of the test.

The reliability of the sit to stand test is not known in this particular group of participants, however the test has been widely used as a proxy for muscle strength and balance in older adults [132;134;135].

3.2.2.8. Statistical analysis

STATISTICA software package for Windows 98 was used for all the analyses (Stasoft, Inc. 184-199, Tulsa OK, USA). Descriptive statistics were performed for the men and women separately, as well as combined. Independent t-tests were conducted to detect significant demographic differences between men and women. Frequency tables were used to determine the percentage of subjects who smoked, those with T-score values below the

WHO guidelines for osteopenia and osteoporosis as well as the percentage above or below the WHO guidelines for anthropometrical measures such as waist circumference and BMI.

The PA data were not normally distributed, and therefore, were log transformed. Results were similar, however, whether or not the data were log transformed. Spearman's rank order correlations were used to examine the associations between historical and current physical activity levels and estimated BMD, BUA, SOS and T-scores. In addition, the associations between estimated BMD and the sit-to-stand test for lower body strength, dietary factors (such as calcium, sodium and alcohol intake), anthropometrical measures, and historical and current physical activity were compared. The analysis of covariance was used to determine the relationship between BMD and smoking status after adjusting for gender. Kruskal Wallis tests were conducted to measure the differences in current energy expenditure between men and women.

Multiple linear regression analyses were performed separately for men and women, first with estimated BMD as the dependent variable and age, BMI, total current energy expenditure and smoking included as independent variables in the model. The multiple regression modeling was repeated, including T-score as the dependant variable.

Repeated measures analysis of variance, with subject as the independent variable and energy expenditure values for each domain of activity (household, occupational and leisure time physical activity) for epochs one to four, as the dependent variable, was performed. Intra class correlation coefficients and 95% confidence intervals were calculated to determine the degree to which household, occupational and leisure time physical activity tracked from epochs one to four. The level of significance for all statistical analyses was alpha < 0.05.

3.3. Results:

3.3.1. Anthropometry

Subject characteristics are presented in Table 3.1. Men and women were similar in age. Women had a significantly higher mean BMI than men (29.6±6.6 and 24.5±5.6, respectively; $p<0.0001$). Nearly half (41%) of the women in the sample were obese (BMI > 30kg/m^2), based on WHO criteria [195], compared to 14% of men. However, mean waist circumference was not significantly different between men and women (90.7±13.6 and 93.9cm ± 13.0, respectively). A greater proportion of women had upper segment body fat distribution compared to men, (64 % vs. 16%), using a waist circumference cut-off value of 88cm for women and 102cm for men [196].

3.3.2. Calcaneal ultra-sound measures

Estimated calcaneal bone mineral density (BMD), T-scores, BUA and SOS results were not significantly different between men and women (Table 3.2). Six percent of the subjects had T-scores of less than -2.5, which is indicative of risk of osteoporosis, while osteopenia risk was found in 52% of the men and 53% of women.

3.3.3. Current habitual physical activity

Results obtained from the YPAS physical activity recall questionnaire are illustrated in Figure 3.1. There was large variability in both the men and women for physical activity levels and the data were not normally distributed. The mean current weekly energy expenditure for household activity was more than two-fold higher in women, 3003±2642 kcal/week, than that reported for the men, (1078±2190kcal/week; $p< 0.0001$). Conversely, the men expended more energy in yard-work activities than the women (298±743 versus 80±202 kcal/week, $p=0.004$). However, total weekly energy expenditure was higher in the women than in the men, (3478±3177 kcal/week and 1906±2709 kcal/week, respectively, $p=0.003$).

3.3.4. Lifetime physical activity

The women had significantly higher household energy expenditure than the men for all of the age epochs (Table 3.3) (p=0.0004). Household activity increased from 14-21 years to 35-49 years, and then decreased from 50-64 years, for both men and women. Conversely, the men had significantly higher occupational energy expenditure values than women did across all age epochs (p<0.0001). Occupational energy expenditure in the men and women decreased at 50-64 years, to values that were similar for the ages 14-21 years.

In this sample population, leisure time PA accounted for a very small amount (0.8% of lifetime EE) of the total energy expenditure, therefore very few of the older adults participated in leisure time activity throughout their lives, which is consistent with other studies evaluating leisure time physical activity among lower socio economic groups [197]. Men had a significantly higher leisure time energy expenditure than the women in epochs one (14-21 years) and two (22-34 years), (p=0.005) (Table 3.3). For the men, leisure related energy expenditure decreased after the 22-34 years, and was zero from 50 years onwards. In the women the decrease was seen after 22 years.

The total energy expenditure (household + occupational + leisure) was similar for men and women for the first four epochs (ages 14 to 64 years). When comparing total energy expenditure of low intensity activities (<3 METs) for the different age epochs, women had significantly higher energy expenditure than men from 14 to 64 years (epochs 1,2,3 and 4), p<0.002. Conversely, men had higher energy expenditure values for activities requiring >3 METs for 22 to 49 years, epochs 2 and 3 (p=0.04).

Trends were similar between men and women for the bone strain units associated with household, occupational and leisure activities. The men had significantly higher occupational bone strain scores for the second, third and fourth epochs (p< 0.0002). Conversely, the women's household bone strain scores were higher than the men for all five epochs (p< 0.03).

3.3.5. Tracking of current physical activity and lifetime physical activity

There is direct evidence that PA patterns tracked from early adult life to the present. Household energy expenditure during ages 14 –21 and 22-34 years were associated with current care giving (child minding or looking after older or disabled adults) for women. For the men, household energy expenditure between the ages of 22 and 49 years were associated with total current expenditure, r=0.31; p=0.045 and r=0.32; p=0.039, respectively. Further, occupation and leisure time energy expenditure at 50-64 years was significantly associated with current yard work activity for the women (r=0.23; p=0.036 and r=0.26 and p=0.032, respectively).

Intra class correlation coefficients (ICC) indicate that activity in all three activity domains in the LTPA questionnaire, tracked from 14-21years to 35-50 years. Household activity in women had a ICC of 0.94, (95% CI: 0.92;0.96), while occupational activity has r ICC of 0.96 (95% CI: 0.95;0.97). The results were similar for men, with household activity having r ICC of 0.87 (95% CI: 0.81;0.92) and occupational activity tracking stronger, 0.96 (95% CI: 0.94;0.98). Leisure time PA showed a weak ICC for the men and a moderate ICC for women, 0.67 and 0.84, respectively.

3.3.6. Current physical activity and estimated BMD

The only parameter measured in the YPAS that was associated with either estimated BMD or T-score was recreational PA (r=0.26; p=0.014 and r= 0.28; p= 0.008, and respectively) among the women. Current household, yard-work, care-giving, exercise and total weekly energy expenditure were not associated with any of the ultra sound measures in both the men and women.

3.3.7. *Lifetime physical activity and BMD*

Total (low plus moderate) occupational energy expenditure was significantly correlated with estimated BMD at 14-21 years in men (r=0.35; p =0.04) (Figure 3.2). For the women, total occupational energy for the ages 22-34 years was positively and significantly correlated to estimated BMD (r=0.24; p=0.03) (data not shown). Household energy expenditure was significantly correlated to estimated BMD amongst the men, (r=0.53; p=0.019) during after 64 years, which also reflects more recent levels of activity.

Total mean energy expenditure (household, occupational and leisure activities, low and moderate) between the ages of 14-21 years was significantly correlated with estimated BMD for men (r=0.39; p=0.017). Similarly, low and moderate intensity (i.e. $\geq$3 METS) for occupational, household and leisure activities combined, were significantly associated with T-scores for male subjects (r= 0.33; p=0.042).

Peak bone strain associated with occupational activity during 14-21 years was significantly correlated to estimated BMD and T-scores (r=0.36;p=0.033) for the men. There were no significant relationships between estimated BMD and peak bone strain associated with occupational, household and leisure time activities for the women

3.3.8. *Other determinants of bone density*

Significant and positive associations between estimated BMD and weight (p<0.003), BMI (p<0.003), waist (p< 0.02) and hip (p<0.02) circumference were observed in both the women the men. T-score did not correlate significantly with any of the anthropometric measurements except BMI (Table 3.4) for men, but was significantly associated with weight, BMI, waist circumference and hip circumference for women.

One third of the men and women reported that they currently smoked. Smokers had significantly lower T-scores and estimated BMD than their non-smoking counterparts. However, there was no association between reported alcohol intake and sit-to-stand measures of lower body strength and estimated BMD or T-score in the present sample. Increased calcium intake was not associated with increased estimated BMD for both the men and women.

A multiple regression analysis model for estimated BMD, which included BMI, lifetime physical activity and calcium intake, provided similar results to the bivariate analyses. Although the models were significant, they only explained a small percentage of the total variance (19% for men and 12% for women).

3.4. Discussion

A major finding of this study was that 52% of men and 53% of women in this cross-sectional sample of older, disadvantaged adults were considered to be osteopenic, according to WHO guidelines for BMD [194]. Furthermore, 7% of the men and 6% of women had T-scores below -2.5 SD, which suggests an increased risk for osteoporosis and hip fracture [110].

The high proportion of male subjects with osteopenia was somewhat unexpected as the ratio of female to male prevalence of low bone mass has been previously documented as 2.0-7.5: 1.0 [198;199]. However, Brown et al. [88], reports that approximately 19% of the Canadian population over the age of 50 years has osteoporosis based on the lowest BMD score obtained from DEXA measurements at the hip, spine and radius. Although men tend to develop osteoporosis later in life than women [200], a low BMD in men, as well as women, places the individual at increased risk for fracture [199;201]. Furthermore, the risk of fracture increases exponentially with age and the mortality rate in men is twice that of women following a fracture [201]. Selective bias may be present as the small number of men in our sample may not be representative of a larger population.

It is unlikely that the large proportion of subjects with low BMD in this study may be attributed to methodological differences including the use of calcaneal ultrasound. Bauer et al. previously validated the use of ultrasound measurement of the calcaneus in a cohort study with 6000 elderly women [94]. Furthermore, the calcaneus is a weight-bearing site and as functional loading improves bone mass, it is influenced by patterns of habitual PA. In addition, calcaneal bone mineral density (BMD) has been demonstrated to be useful in screening for spinal osteoporosis BMD [97].

Another important finding was that PA during the first age epoch (14-21 years), related to occupational activities, was significantly correlated to estimated BMD and T-score in men. For the women, occupational PA had a positive and significant correlation with estimated BMD between the ages of 22-34 years (second epoch). The relationship between occupational PA and T-score approached significance in the women (r=0.21; p=0.055) for the ages 22-34 years. It has previously been shown that increases in occupation, leisure and sport-related energy expenditure may increase peak bone mass and thereby reduce the risk of osteoporosis in young women [202]. Similarly, Kriska et al. investigated the relationship between baseline bone measurements and historical leisure PA in postmenopausal Caucasian women and found a significant, but weak relationship between activity levels and bone area and density [81]. These authors found that bone area, not density, was significantly correlated to PA during the earliest time period, 14-21 years. These two epochs (14-21 years and 22-34 years) represent the ages during which peak bone mass is achieved [99] and PA appears to play a vital role in achieving peak bone mass [202].

Leisure time activities were not associated with the calcaneal ultrasound parameters for all the age epochs in our sample. Similarly Brahm et al. found that calcaneal ultrasound measures and BMD measured by DEXA were not consistently related to lifetime leisure activities in men and women 22-85 years old [110]. Conversely, Teegarden et al. found that energy expenditure associated with high school sport was a predictor of femoral neck BMD, total body BMD and BMC (bone mineral content) and spine BMD and BMC in 18-31 year old Caucasian women [202]. In addition, a positive relationship was found between lifetime exercise and total hip BMD in Caucasian men and women older than 60 years [105]. The differences between the results of Teegarden et al. [202] and those of the present study, as well as Brahm et al. [110], may be related to the differences in age of the subjects, as well as the fact that lifetime occupational and leisure time activity were included, compared to only high school sports, and activities within the preceding five years.

Furthermore, the low estimated BMD found in the present study, together with a low prevalence of leisure time PA (only 0.8% of total energy expenditure), may have contributed to the lack of association between leisure time physical activity and estimated BMD. A low level of leisure time PA has been associated with individuals who have a low income and educational levels [197] and in those who have high levels of occupational activities [203]. Thus the measurement of leisure time activity in our population yielded results that are consistent with the literature. However, since leisure time PA has not been previously quantified among these older adults, we included this domain together with occupation and household activities, so as to provide an estimate of total energy expenditure and to gain insight into activities commonly performed by these older adults.

Current PA has been shown to play an important role in maintaining bone density and reducing the rate of bone loss that occurs with aging [204]. This effect is more specific to the skeletal sites used during the activity [187;205]. The reported weekly energy expenditure of our sample was less than half of that reported for older North Americans using the same questionnaire [19], but were similar to those reported in a Cape Town (urban) sample [9]. We found a significant correlation between current recreational PA measured by the YPAS questionnaire and estimated BMD for the women (r= 0.26; p=0.013) and T-score (r=0.28; p = 0.007). We considered the possibility that these recreationally active women were "self-selected", as they may have had higher energy expenditure levels in the previous age epochs. The high intraclass correlation coefficients obtained when tracking PA in household, occupational and leisure domains, demonstrates that those who were active in epoch one were more likely to be active throughout life. These findings are supported by those of Kriska et al. (1986) who found that early exercise participation predicts future participation in older women [206].

Eventhough habitual physical activity tracked from 14 years, there was a decrease in habitual energy expenditure. This decrease in physical activity with age has also been well documented in developed countries [21-24]. Furthermore, Evenson et al. reported that for those indivudals who have physically active occupations, retirement may result in a decline in habitual PA levels [33]. Thus it is possible that the odler adults participating in our study, particularly the men may have experienced a decrease in habitual physical activity after retirement, which might negate the positive effect that exercise has on BMD.

Indeed, none of the measures of current PA in the present study were significantly associated with bone parameters in the men. This is similar to the findings of Glynn et al. who investigated the determinants of BMD amongst men 50 years or older [207]. The significant relationship between low intensity household activities (measured in the LTPA questionnaire) and estimated BMD for men over the age of 64 years can be explained by the fact that only a small percentage of the sample comprised of this age group. This is supported by another study in which men who participated in 7 hours per week or more of either gardening, outside repairs, heavy indoor chores or recreation related activity had a reduced risk of fracture [201].

Bone strain is the degree to which the bone tissue is temporarily deformed when a force is applied [208]. Groothausen et al. found that peak strain physical activity from 13-27 years was a significant predictor of lumbar BMD for 27 year olds in both males and females [190]. The bone strain for occupation- related activities for the first epoch in the current study was significantly correlated to estimated BMD and T-score in the men, and may be due to the fact that most of the men in the current study performed manual labor in the fishing industry.

However, peak bone strain in the women was not related to BMD or T-score for the first four epochs. Most of the activities performed by women were of a low to moderate intensity, and may explain in part, the familiar association. Jakes et al. reported that high, not moderate impact activity was associated with ultrasound attenuation [106]. Therefore, activities that are most commonly performed in daily living such as walking may not be as effective with regard to bone mineral accretion [99]. Unfortunately, we were unable to analyze walking as a separate parameter to household, occupational and leisure activities given that our subjects included walking in their estimates of energy expenditure for these three domains.

Furthermore, Prior et al. stated that greater loads and fewer repetitions of the load results in greater gains in bone mass than a higher number of repetitions at a smaller load [204]. Most of the women in our study worked as packers in a fish factory and stood for most of their working day. Therefore, the activities performed by the subjects in our study, particularly the women, may not have induced sufficient strain to ultimately result in greater bone mass and density.

We also investigated the association of potential cofounders for the relationship between estimated BMD and lifetime PA, such as diet (calcium and alcohol consumption) and smoking status. No association between reported calcium intake and estimated BMD was found which is in agreement with the findings of Ward et al. [209]. The results between these two studies are similar, despite the fact that the calcium intake in the study by Ward et al. was calculated as the sum of milk, yogurt, cheese and ice cream consumption, while in the present study, calcium intake was derived from a semi-quantitative food frequency questionnaire for the previous two weeks [209].

The association between BMI and estimated BMD was significant for the women and also the men. BMI has been previously shown to be associated with BMI among women [101;209]. For example, Saadi et al. found that BMI, together with age and PA, was a significantly associated with ultrasound measures [101]. The Arabian women participating in their study had similar BMI values to those participating in the current study, (27.3 ± 5.5 vs 29.5 ± 6.7). The significant association between BMI and estimated BMD found among the men is similar to Kirchengast et al's findings [210]. These researchers found the BMI, and lean body mass, but not stature was significantly associated with hip BMD men aged 60-86 years.

Excessive alcohol intake has been shown to increase the risk for osteoporosis. However, reported alcohol intake in the present study was not associated with estimated BMD. This is similar to the findings of Ganry et al. in which they found that alcohol consumption was not associated with femoral neck BMD [211]. However, moderate intake, but not light or heavy intake, was associated with (11-29g/d) a higher trochanteric BMD in the same sample if women [211]. Therefore the effects of alcohol; intake on BMD appears to depend on the site being measured.

Furthermore, the participants in our study may have under reported their habitual alcohol consumption, particularly those who consumed larger amounts of alcohol. Ganry et al. indicated that the underreporting of habitual alcohol, particularly among heavy users, would reduce the differences between one category of drinker with another, e.g., moderate versus high. This in turn would result in a reduction of the probability of a significant relationship between alcohol consumption and BMD [211]. Indeed, the beneficial effects of alcohol on BMD was not present among the women who reported consuming more than 30g or less than 10 g of alcohol per day [211].

Smokers in the current study had lower estimated BMD. This is supported by Ward and colleagues who found that smokers tend to have lower BMD values and a greater rate of bone loss compared to non-smokers [209]. In addition, it has been reported that current smokers had a higher risk for hip fracture compared to never smokers or ex-smokers [212]. A dose response was reported [212], with those smoking more cigarettes per day having a greater risk than those smoking fewer cigarettes per day.

Ethnicity has also been identified as an important determinant of BMD, as Caucasian women are consistently shown to have lower BMD than African Americans [213-215]. The participants of our study were from a single ethnic group with a diverse ancestry, therefore few comparisons could be made within the study sample. However, a South African based study [216] found no significant differences between BMD at the lumbar spine or proximal femur between women from the Mixed Ancestry group and Caucasians. Conversely, the South African women had significantly lower lumbar spine BMD, when compared to an age matched American database.

Furthermore, the reference data for osteoporosis and osteopenia has been derived from largely Caucasian based populations and may therefore not be relevant to other ethnic groups [213]. Broussard and Magnus compared the use of the reference values for osteoporosis and osteopenia that were based on a Caucasian population, in African Americas, Mexican Americans and Caucasians [213]. The prevalence of osteoporosis in the African American and Mexican America men and women increased when race and gender specific T-scores were used, compared to the Caucasian based reference values. The participants of our study were from the Mixed Ancestry racial group, and their ancestry includes African, European and Malay origin, as well as those from the Khoi San tribes, which were the indigenous people residing predominantly in the Western Cape. Thus, more research in the Mixed Ancestry racial group is required not only to provide direct comparisons of BMD with other ethnic groups, but also to establish population based reference values.

One of the limitations of the current study may have been the subjects' ability to accurately recall the mode and duration of various activities for earlier epochs. Chesen-Taber et el. [164] evaluated the reproducibility of the lifetime physical activity questionnaire developed by Kriska et al. [81] and the correlation between the first and second administration of the questionnaire was r = 0.83 for women aged 51-65 years. Therefore, the questionnaire appears to be reproducible [164]. In addition, Blair et al. investigated the accuracy of recall of leisure time physical activity in 451 middle aged white collar workers (mean age 41.3 years) and found that associations between current and past activity were modest but significant [217]. Furthermore, Falkner et al. compared the response to PA questionnaires obtained in 1962 to those obtained between 1992 and 1996 and reported that individuals can recall weekday occupational and leisure time activity that occurred in the distant past; and the ability to recall PA did not decline over time periods longer than 10 years [123].

A second limitation was that were not able to ascertain the period of time elapsing since the onset of menopause as a potential confounder in our analysis. In light of the low socio-economic status of the community, the limited health care services available, and previous reports that African women are largely unaware of hormone replacement therapy, it is highly unlikely that the women in our study would have been receiving hormone replacement therapy [218].

Lifetime nutrition and access to health care may also explain the high prevalence of low estimated BMD in our sample, and it would therefore be an important variable to include in future research studies.

Another limitation is the relatively small sample size, particularly for men. However, the results obtained indicate that this population may be at increased risk and therefore encourages further investigation into the relationship between physical activity and bone mineral density in non-Caucasian men and women who had physically active occupations of low socio-economic status.

3.5. Summary

Historical occupational related PA in men in early adulthood (14-21 years) was weakly but significantly correlated to estimated BMD in men. In women, the occupational related PA was significantly correlated with BMD, and T-score between the ages of 22 and 34 years.

Current levels of activity, especially leisure time activity, in this population were low, and were not associated with BMD amongst the men. However, for women, current recreation PA was significantly associated with BMD, BUA and T-score. Moreover, PA "tracked" across all epochs.

Both older men and women sampled from this community may be at increased risk for fracture and morbidity due to low estimated bone mineral density, despite the apparent "protective" effect of lifelong levels of occupational (men) and household (women) PA. From a public health perspective, these data highlight the importance of quantifying lifetime physical activity in all domains, including occupation.

In addition to low BMD increasing the risk of osteopenia and osteoporosis it has also been associated with increased risk for disability [219]. Taaffe and co workers found that low femoral neck BMD was associated with knee extensor strength, sit to stand performance, gait speed and balance among Black women [220]. In addition, lower total body BMD was associated with increased need for assistance in IADL [219]. Increased dependence in IADL, together with impaired performance in functional tasks such as the sit to stand tests, gait speed and balance, are all associated with increased risk of frailty and disability.

Furthermore, low BMD has also been identified as a risk factor for future fracture in both men and women [221]. The increased risk of fracture, which could be a fall related injury, is another factor that may play a role in an older adult becoming frail or disabled. For example, following a fall, the once independent individual may rely on others for assistance with ADL's and IADL's. Therefore, these older adults may be at increased risk of frailty and disability in addition, to being at risk for osteopenia and osteoporosis.

The following chapter will investigate the parameters associated with frailty and disability in older adults from low socio economic status and low educational levels.

Table 3.1: Subject characteristics. (Mean ± Standard deviations)

Variable	Total		Females		Males	
Age (years)	66	± 7	66	± 7	66	± 8
Hip (cm)	105.9	± 15.3	109.5	± 15.8	97.3	± 9.7
Waist (cm)	92.9	± 13.2	93.9	± 13.0	90.7	± 13.6
BMI	28.2	± 6.7	29.6	± 6.6	24.5	± 5.6
Calcium Intake (mg/day)	534	± 334	532	± 362	539	± 260
Alcohol Intake (g/day)	11.4	29.0	2.2	± 8.4	32.2	44.6
Smoking (% yes)	35%		29%		49%	
Hypertension (% yes)	74.3%		76%		71.1%	
Diabetes (% yes)	45.2%		48%		33.3%	

Table 3.2: Bone health parameters in men and women. (Mean ± Standard deviations)

Variable	Total		Females		Males	
BMD ($g{:}cm^{-2}$)	0.45	± 0.1	0.45	± 0.1	0.45	± 0.1
T-Score	-1.06	± 1.00	-1.05	± 1.01	-1.10	± 0.99
BUA (dB/MHz)	54.81	± 16.37	53.66	± 16.15	57.22	± 16.75
SOS	1541.81	± 25.86	1542.24	± 26.03	1540.94	± 25.76

Table 3.4: Spearman's rank order correlation coefficients (unadjusted) for the association between estimated BMD, BUA and anthropometrical measurements in men and women.

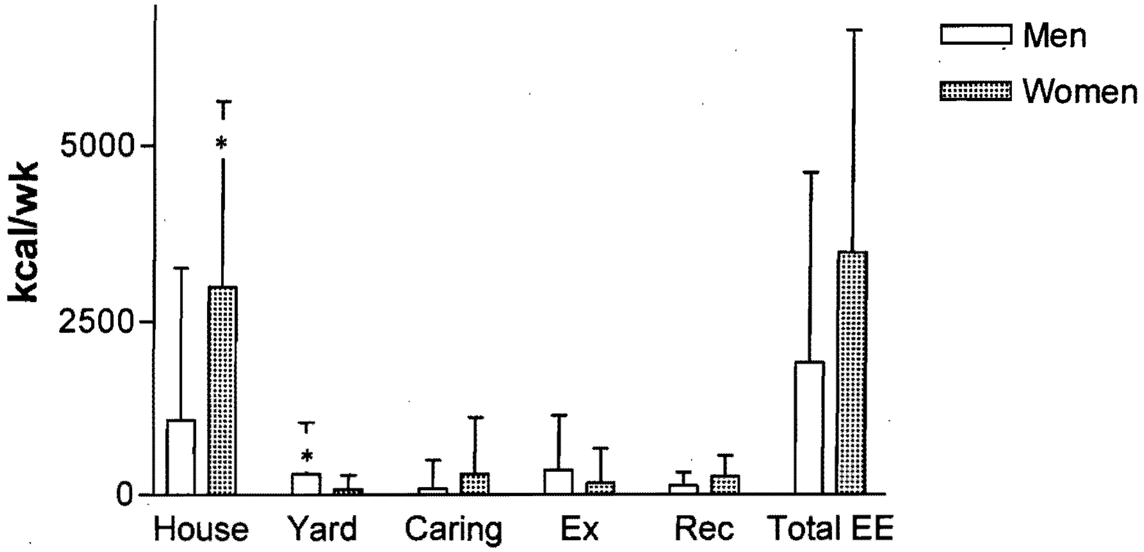
	Women			Men		
	BMD	BUA	T-score	BMD	BUA	T-score
Weight						
r	0.31	0.37	0.32	0.36		NS
p	0.002	<0.001	0.001	0.02		
					0.46	
					0.003	
BMI						
r	0.32	0.35	0.32	0.48	0.55	0.38
p	0.001	<0.0001	0.001	0.002	<0.001	0.02
Waist						
r	0.25	0.27	0.27	0.37	0.49	NS
p	0.002	0.012	0.008	0.02	0.001	
Hip						
r	0.30	0.32	0.30	0.38	0.43	NS
p	0.003	0.002	0.002	0.017	0.006	

NS = Not significant

Table 3.3: Lifetime Physical Activity for household, occupation and leisure time related activity in men and women for epochs 1 – 5.
(Median, inter quartile range)

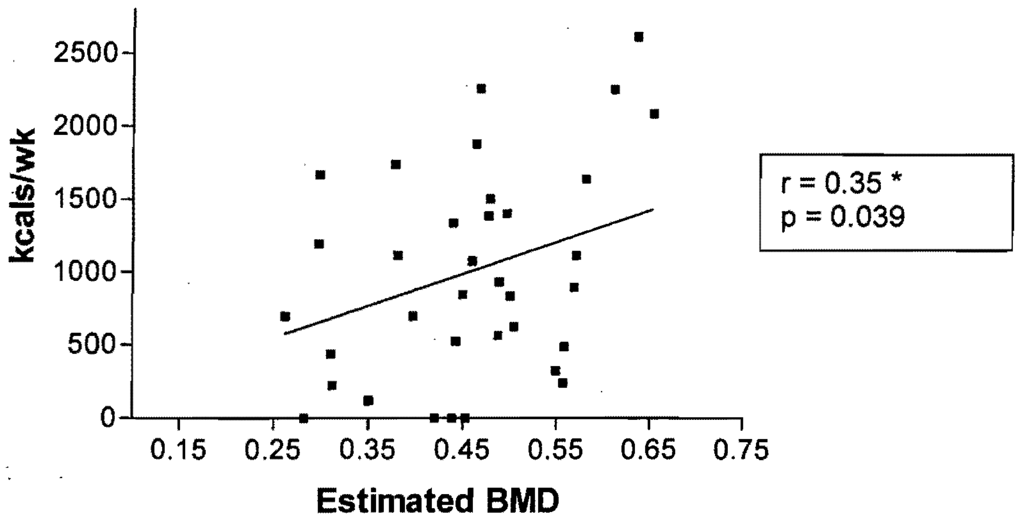
	Men			Women		
	Household	**Occupation**	**Leisure**	**Household**	**Occupation**	**Leisure**
Epoch 1(14-21 years) [MET hrs/wk]	136 (0-333)	1000 (437 – 1503)	10 (0 – 74)	586 (189 – 1695)	714 (323 (1042)	0 (0 – 17)
Epoch 2 (22-34 years) [MET hrs/wk]	217 (0 –454)	2382 (1429 – 3215)	0 (0 – 4)	715 (324 – 2905)	1191 (186 – 1771)	0 (0 – 0)
Epoch 3 (35-49 years) [MET hrs/wk]	277 (0 – 834)	2602 (1340 – 3639)	0 (0 – 0)	883 (379 – 3372)	893 (0-1737)	0 (0 – 0)
Epoch 4 (50-64 years) [MET hrs/wk]	189 (0 – 577)	1151 (0 – 1997)	0 (0 – 0)	538 (318 – 2726)	0 (0 – 750)	0 (0 – 0)
Epoch 5 ($\geq$ 65 years) [MET hrs/wk]	54 (0 – 360)	0 (0 – 0)	0 (0 – 0)	261 (113 – 1025)	0 (0 – 0)	0 (0 – 0)

Figure 3.1. Current weekly energy expenditure (kcal/wk) for men and women



Legend: House = household related activities; Yard = yard-work and gardening related activities; caring = activities related to caring for an older person or child; Ex = exercise related activities; Rec = recreational related activities; Total EE = house + yard + caring + exercise + recreational activities.
* - Differences between energy expenditure for men and women where p < 0.005

Figure 2: Association between BMD and occupational related energy expenditure in the men for age epoch 1 (14- 21 years).



Spearman's rank order correlation coefficient (unadjusted)

CHAPTER 4

THE COMPARISON OF SELF-REPORTED FUNCTIONAL IMPAIRMENT, MEASURED BY THE DISABILITY 1998 QUESTIONNAIRE (DQ 98) AND OBJECTIVE FUNCTIONAL PERFORMANCE TESTS IN XHOSA OLDER ADULTS.

4.1. Introduction

In the previous chapter, we found a high prevalence of low estimated BMD in both men and women, using calcaneal ultrasound. Low BMD has been associated with increased risk of fracture, and also with reduced functional performance for tests such as the sit to stand and balance tests. Reduced functional ability may lead to frailty or disability and therefore, adversely affect the older adult's quality of life. Furthermore, increasing age, together with the loss of functional ability may lead to increased dependence on others for assistance and result in the need for institutionalized care.

The need for institutionalized care is an important consideration as the proportion of the older adult population increases within South Africa, the number of disabled elders needing long-term care will also increase. According to Tennstedt and McKinlay, the State is reaching its limits in financial resources available for the care of frail elders in the most developed countries [222]. For example, in the United States, 47% of individuals who are 65 years in 2015, will survive to 85 years or older, and will account for 63% of total health care expenditure [223]. Individuals aged 85 years and older are projected to represent an increasing proportion of the elderly population, and their health care expenditures will account for 60% of the older adult cohort [223]. Furthermore, it has been demonstrated that individuals who are institutionalized at 70 years old have higher cumulative health care expenditures than their community dwelling counterparts [224]. Therefore, the greatest financial benefits may be obtained by preventing older adults from becoming dependent [225].

If South Africa, as a country undergoing rapid demographic transition, is following the trends of the other developed countries, structures and guidelines need to be formulated so as to ensure that both the current and future needs of the frail older adult are met with the limited resources available. Indeed, since the year 2000, institutionalized care in residential homes for the older adult has been primarily reserved for those who are classified as frail and in need of care [226]. Thus the admittance criteria to an old age home, or institution are largely based on the individual's level of dependence or frailty. Consequently, the definition and measurement of "frailty" have become increasingly important.

Most researchers agree that frailty is a multidimensional concept, which includes loss of reserve, feebleness, vulnerability, the presence of impaired physiological function, either with our without the presence of disease [143;227]. Definitions of frailty that have been used are typically based on the individual's ability to perform the ADL independently [143]. In addition, the term frail is often used to describe institutionalized older adults [147] which means that individuals who are frail or at risk of becoming frail and are not living in old age homes may be excluded from this definition. Consequently, an individual applying for residency may not be sufficiently frail at the time of application, but may deteriorate to severely impaired by the time a vacancy exists at the senior center. Alternatively, an individual that is classified as frail may never apply for permanent residence at an institution.

Campbell and Buchner have distinguished between being frail and disabled [112]. They defined and diagnosed frailty as the "instability and risk of loss, or further loss of function". Furthermore, they consider frailty to be a syndrome of multi-system reduction in physiological capacity that results in an older person's function being severely compromised by even minor environmental challenges. Disability was described as a loss of function which may in part be due to a single catastrophic event in an otherwise healthy, functionally independent individual who, although experiencing some loss of function, remains functionally constant at this level. The researchers defined unstable disability as a state when "function fluctuates markedly with external events" in such which may result in further loss of function. Frailty was therefore, identified as "the root cause for unstable disability".

Several studies that have enrolled subjects across a wide spectrum of physical performance have found consistently that physical performance is associated with prevalent disability or risk of incident disability. Research by Rantanen et al. found that severe motor disability was associated with lower levels of habitual physical activity, which in turn was associated with poor muscle strength [125]. Low performance in walking speed and increased disability in ADL was also associated with frailty in a study conducted by Chin A Paw et al. [147]. In addition, balance impairment has been identified as another facet of physical frailty. For example, the individual's ability to reach forward beyond arms length while maintaining a fixed base of support (functional reach) has been correlated to physical frailty [228]. These measures of frailty together with self reported measures of activity are useful markers of frailty and predictors of institutionalization in older adults [229].

Chin a Paw et al identified physical inactivity and malnutrition as two of the major determinants of functional dependance [147]. This is in part due to the fact that inactivity may cause a decrease in appetite and reduced dietary intake, which in turn results in malnutrition, muscle weakness and reduced functional ability, further inactivity. These researchers classified individuals into three categories of frailty, based on low levels of physical activity combined with either; a) low dietary energy intake, b) weight loss more than 4kg in the past five years, or c) Body Mass Index (BMI) less than 23.5 kg/m^2.

Another problem that arises with the concept of frailty is classification. Different patients will present with different degrees of frailty and their own condition is not static in nature [230]. Winograd et al. [231] reported that those patients who were classified as frail presented with criteria such as; dependence in ADL, cerebrovascular accident, chronic and disabling illness, falls, impaired mobility, incontinence, malnutrition, sensory impairments and poly-pharmacy. Increasing frailty has been significantly correlated to increased length of hospital stay and nursing home utilization. Campbell and Buchner, suggest that frailty can be diagnosed by clinically measuring four key components, namely, musculo-skeletal function, aerobic capacity, cognitive and integrative neurological function and nutritional state [112].

These four components may be measured using questionnaires or self-report based tools, and also objective measures of functional performance. Measures of mobility impairment and functional status are of value to the older adult population, as they have been show to be related to the need for institutionalization and mortality [232]. Performance based measures are more objective and can complement information obtained from self-report measures (such as questionnaires) since they are less influenced by language and cultural challenges [225]. However, self-report measures are easier to administer and require minimal equipment.

A questionnaire to measure self-reported disability has been developed specifically for South African older adults. The Dependency Questionnaire 1998 (DQ 98) was designed by the South African Department of Welfare to assess the needs of persons applying for or requiring frail care and support services. The questionnaire encompasses socio-demographic factors, socio-economic status, ADL, mental health status, availability and effectiveness of current care / assistance and availability of resources such as water and transport. A score is obtained for primary care needs (such as bed rest, assistance with medication, night care), ADL, mental health, primary needs (availability of water and transport) and current care received. Each of these scores is weighted to obtain a composite score which determines the participants' urgency for admission into a frail care center or nursing home.

The DQ 98 is based on self-report and therefore no provision has been made to evaluate the applicant's functional ability. Performance-based measures of functional status are of value as they are less dependant on educational status and language, and may therefore be more objective than self report or questionnaire-based assessments [225]. Therefore, the objective of this chapter is two fold; firstly to compare objective functional performance measures with the self-reported disability that will be assessed using the DQ 98 questionnaire between community dwelling and institionalised older adults. We hypothesized that the DQ98 scores would be inversely related to the functional measures of frailty.

Secondly, based on the variations in the definition of frailty, we compared two measures of frailty to objectively measured functional ability in older Xhosa speaking South Africans who were both community dwelling and institutionalized. For the purpose of this study, frailty was defined as low BMI coupled with low levels of PA, and impaired cognitive function. Low BMI was therefore used as one of the criteria to define frailty in this study, since it might indicate insufficient nutrition and has previously been shown to be a risk factor for mortality among the older adult population. Furthermore, it is possible that low levels of physical activity is related to inadequate energy intake, and was thus included as part of the definition of frailty. Because frailty is a multi dimensional concept, we hypothesized that low BMI coupled with low PA levels, would have stronger associations with the functional measures than cognitive function alone.

4.2. Methods:

4.2.1. Sample:

Xhosa speaking South Africans (n=221) older than 60 years and who were either free living in the community or institutionalized participated in this cross sectional analytical research study. Community dwelling participants were recruited from luncheon clubs and church groups in the Cape Peninsula. In addition, we recruited residents from state subsidized old age homes. An original sample of 283 men and women were recruited, however, due to missing data, we included 221 older adults in the analyses.

4.2.2. Measurements:

4.2.2.1. Questionnaires

4.2.2.1.1. The Dependency Questionnaire 1998 (DQ 98)

The DQ 98 is an interviewer-administered questionnaire that determines an applicant's socio demographic and economic status as well as the level of care required, dependence in ADL, mental functioning and primary needs. The points or scores allocated for each of these domains are hierarchical and where a higher score reflects a greater amount of assistance required by the older adult.

The skilled care score is the sum of three care giving scores, namely pressure care, specialized care and night care. The pressure care score relates to care required for conditions such as bed sores, and ranges from zero for no care required, to 33 for care required every two hours. Specialized care for wound dressings has a maximum score of 42 if the older adult requires their wound dressing to be changed more than three times per day, and has a minimum score of zero if no care is required. No, or infrequent night care is scored as zero, regular (once per night) care is scored as 5, care required 3 times per night is scored as 10 and if the older adult is frequently awake at night and disturbs others, they receive a score of 25.

The current level of care being received is scored according the availability of a caregiver, and whether they are able to cope with all the responsibilities associated with caring for the older adult. For example, if the care giver is in control of the situation a score of zero is allocated, but if they require some assistance or are not healthy themselves, then a score of 7 is allocated. Conversely, if the caregiver is "burnt out" then a score of 67 is awarded.

The DQ 98 ADL score is based on the level of assistance required for the following activities; bathing, dressing the upper body, dressing the lower body, personal hygiene, eating, toileting, medications, mobility, communication and transfers. The amounts of assistance for each of the tasks are described as; fully independent; independent with aid / devices; needs supervision but can manage on own; needs regular supervision and help with certain tasks; needs help of one person; needs help of two persons; and needs continuous care. The scores for each of the ADL tasks range from 0 for no assistance required to 10. These scores are summed to calculate the e total ADL scores which range from zero to a maximum of 83, with a higher score reflecting greater dependence or functional impairment.

The availability of resources such as water, food, ablution facilities and safety in living environment is assessed and classified as primary needs score. The minimum possible score is 0, if the resource is available, to 28 if the resource is absent. A subjective evaluation by the interviewer determines the mental functioning scores, which ranges from no support required to behavior dangerous to him / herself and others.

Each of the individual DQ98 scores (care giving, ADL, primary needs, skilled care, mental functioning) are further weighted and summed to calculate a DQ 98 index score that rates the urgency for the applicant's admission into a nursing home or institution. A higher score indicates a greater degree of dependency and urgency for admission.

4.2.2.2. Demographic and health status

An interviewer-administered questionnaire was conducted to obtain information about the subjects' age, marital, occupational, health, economic and educational status. The participants were asked to rate their health status using a five-item scale and also to compare their health to others' the same age. In addition, participants were asked if they had been previously diagnosed by a doctor and taking medication for any of the following conditions; hypertension, heart disease, stroke, hypercholesteroleamia, diabetes mellitus, asthma, or peripheral vascular disease.

4.2.2.1.3. Activities of daily living (ADL)

For purposes of comparison, a separate questionnaire assessed ADL using the 10-item Barthel index. Participants were asked to rate their ability to perform each of the ADL tasks as either a) independent/ without help, b) able to, but need help, or c) unable to perform activity independently. The tasks evaluated were; dependency in bowel continence, bladder continence, grooming and self cleaning, toilet use, feeding, transfer, mobility, dressing, stair walking and bathing. For the Barthel index, the scored ranged from 2 if subjects were able to perform a task independently to zero if they needed assistance or were unable to perform the task, except for mobility where a 4 point scoring system was used. Thus, the scoring for the Barthel index ranged from 0 to 20, with a higher score representing a higher level of independence.

4.2.2.1.4. Instrumental Activities of Daily Living (IADL)

Lawton's questionnaire assesses the ability of subjects to perform eight tasks either a) without help, b) able, but need some help, or c) completely unable to perform tasks [233]. The tasks include ability to travel to places further than walking distance, shopping for groceries, preparing meals, doing housework or handyman work, laundering clothes, using the telephone, and taking medication and managing money. Requiring help or the inability to perform a task is coded as dependent, and a score of 1 and zero, respectively, is allocated. Independence in a task is scored as 2. Therefore, subjects may have a score ranging from zero to 16, where the more independent older adult will have a higher score.

4.2.2.1.5. Yale Physical Activity Survey

Current habitual PA levels were assessed using an adapted interviewer-administered version of Yale Physical Activity Survey (YPAS) for older adults [19], as described in chapter 2, section, 2.2.3.1.

4.2.2.1.6. Cognitive Performance

The six-item cognitive impairment test (6CIT) was developed in the United Kingdom to assess cognitive function in older adults by measuring orientation, concentration and memory. The first three questions assess orientation in time, by asking the participant to recall the current month and year. The latter three questions assess memory and concentration. This tool was modified by Broderick [234] for use in African Xhosa-speaking older adults and has been previously validated against the Bristol Activities of Daily Living scale (BADL) [235]. The memory phrase in the adapted 6CIT was a five-item phrase, representing a local address, "Pumla/Zibi/Z69/Jama Road/Khayelitsha".

The number of errors made by the participant for each question is scored and weighted. The maximum number of errors required for recalling the year, month and time was 1, and these score obtained was multiplied by 4, 3 and 4 respectively. Two errors were allowed for counting backwards and recalling the months in reverse order, and the number of errors made were multiplied by 2, for each of these questions. Lastly, a maximum of 5 errors was allowed for recalling the memory phrase, and the number of errors made was multiplied by 2. Each of the weighted scores was then summed to calculate the total 6CIT score.

The total 6CIT score range from zero to 28, where a higher score indicates severe dementia. In one of the earlier validation studies for the 6CIT, by Brooke et al. [236] a cut off score of seven or eight was recommended as an indication that the participant required further investigation or an intervention program. Katzman and colleagues suggested that a cut-off score of 10 be used as an indication of dementia [237]. We used the score of 15 recommended by Broderick [234] as indicative of dementia, based on her sample of 92 Xhosa speaking women.

4.2.2.1.7. Motor Disability

An index of motor disability was calculated as the sum of self reported difficulties in six different tasks. These tasks were walking across a small room, walking 400 m, and walking up 10 steps, doing heavy household work, using fingers to grasp or handle and lifting 4.5kg. The sum of disability scores ranged from six to 12, with higher scores indicating greater functional ability [125].

4.2.2.2. Functional performance tests:

The following seven functional performance tests were performed. The results of each of the individual functional performance tests were rated with scores ranging from zero, indicating inability to perform the function; to four, indicating excellent ability.

4.2.2.2.1. Static Balance Test:

Static balance was assessed by asking the participant to stand for as long as possible (a maximum of 30 seconds) under the following stance conditions; comfortable stance (feet shoulder width apart), narrow stance (feet together) and tandem and semi tandem stance with the left then right foot leading. If the subject failed to maintain the stance for 30 seconds, a second attempt was allowed and the average duration of the two attempts was recorded [231].

The ability to maintain balance for 10 seconds in the tandem (left and right foot leading) and semi tandem stance (left and right foot leading) as described by the Romberg balance test [117] was evaluated. The score is the number stances the subject managed to maintain for 10 seconds. A score of 4 indicated the ability to maintain all 4 stances for 10 seconds; and zero indicated that the participants was unable to maintain 10 sec for any of the four stances. Scores ranged from zero to four where a higher score indicated better functional status [114].

4.2.2.2.2. Dynamic balance

The participants walked six steps along a strip of tape using the tandem gait. Tandem gait involves walking toe to heel, i.e., when the left foot is in front, the right toe will move forward touching the left heel [115]. Scoring for dynamic balance was as follows: 4 = does 5-6 steps successfully, 2= does 2-4 steps successfully, 0 = does less than two steps successfully [228]. In addition, the time taken to walk 6 steps using the tandem gait was being recorded [231].

4.2.2.2.3. Functional Reach

Participants were asked to reach as far forward as possible along a wall mounted yardstick without moving / taking a step [228]. Participants were given two practice trials and then three more trials. The mean value of the last three trials was recorded. This test has been validated by Weiner et al. [228]. Functional reach was scored as follows: 0 = unable to reach; 1=≤80cm; 2=80-90 cm; 3=90-100cm; 4=≥100cm.

4.2.2.2.4. Chair rise

Participants were instructed to rise from a chair and sit down again five times as fast as possible, whilst keeping their arms across the chest. The time taken to perform the task was recorded [133]. If the participant was unable to complete all five repetitions, the number of repetitions and the respective time taken was recorded. Chair rise was scored as follows: 0 = unable; 1=<5 repetitions completed; 2=>25 seconds to complete 5 repetitions; 3= 15-24 seconds; 4=<15 seconds.

4.2.2.2.5. 8-Foot walk

The time (in seconds) and number of steps that is required by each participant to walk 8 feet (2.44 m) at habitual pace was recorded [133]. The score was based on walking speed, the equivalent measure of time taken to walk the distance, as follows: 0 = unable; 1=>10 seconds; 2=7-10 seconds; 3=5-6 seconds; 4=<5 seconds.

4.2.2.2.6. Grip strength

Grip strength was determined using a hand held dynamometer and measured in kg of isometric force. Participants were instructed to squeeze as hard as possible without bending the elbow, while remaining seated. The maximum value of four attempts; comprising of two attempts for each of left and right arms, was recorded. Grip strength was scored as 0=<10; 1=10-15; 2=16-20; 3=21-24; 4=>25.

4.2.2.2.7. Timed up and go test

Participants were required to start in a seated position on a standard chair, then stand up, walk 3m, turn around, walk back to the chair and sit down. The time taken to complete the task was recorded [115;238]. Timed up and go scores were allocated as follows;: 0=unable; 1=≥20 seconds; 2=15-19 seconds; 3= 11-14 seconds; 4 = <10 seconds

4.2.2.2.8. Functional ability index score (FAIS)

The sum of each of the scores obtained from the functional tests described in sections 4.2.2.2.1 to 4.2.2.2.7. was calculated in order to obtain the FAIS. Possible scores are zero to 28, where a higher score indicates greater functional ability. We categorized those scoring less than 7 as high risk for frailty as an individual scoring less than 7 for the FAIS would either be unable to perform some of the tests, or score an average of 1, which is the lowest functional category, for most of the tests. Those scoring an average of 3 for the functional tests would score 21 or more, and were therefore regarded as low risk for frailty. Scores ranging from 8 to 20 placed the participant in the moderate risk group.

Fried et al. described a frailty phenotype based on unintentional weight loss, exhaustion and depression, habitual physical activity, gait speed and grip strength [239]. Gait speed and grip strength were scored in the current study in order to provide a functional ability score adapted from Fried et al. [239]. The remaining variables, weight loss and depression and exhaustion were not measured in our study, and were therefore excluded from the overall functional score based on Fried et al.

Furthermore, an additional functional ability score was calculated according to the guidelines described by Guralnik et al. in the Established Populations for Epidemiologic Studies of the Elderly (EPESE) [133]. The functional ability score for the EPESE was calculated by summing the values obtained for the sit to stand, static balance and gait speed tests.

The FAIS, adapted Fried et al and EPESE scores were compared with each other and the DQ98, YPAS and the individual functional performance test scores.

4.2.2.3. Anthropometrical assessment:

Height was measured without shoes, using a wall mounted tape measure and recorded to the nearest centimeter. Body mass was measured using a scale and recorded to the nearest 0.5 kg. BMI was calculated as body mass (kg) divided by height (m) squared (kg/m^2).

4.2.2.4. Constructs of frailty:

Chin A Paw et al. previously compared three working definitions of frailty with health, mortality and functional status [147]. The three definitions described by Chin A Paw et al. were low PA coupled with either, low BMI, or unintentional weight loss, or low energy intake [147]. These researchers found that the definition combining low levels of PA with unintentional weight loss had stronger associations with lower subjective health rating and more diseases and disabilities than two other definitions. Because we were unable to determine weight loss in our sample, we used the definition combining low PA with low BMI (PA+BMI), as a construct of frailty.

In addition, because frailty has been previously associated with impaired cognitive function, we compared those with a cognitive score less than 15 to those with a score more than 15 [234]. A lower score is indicative of better cognitive function, therefore those with a score less than 15 were regarded as at low risk of frailty.

4.2.3. Statistical Analysis:

Descriptive statistics are presented for the total sample and also for the men, women, community dwelling and institutionalized sub-samples separately. Means and standard deviations are presented where the data were normally distributed, and as median and 25th and 75th centile, where the data were skewed. Frequency tables were computed for categorical variables, and also to determine the percentage of participants with scores in predetermined ranges. The Mann-Whitney tests were used to determine if there were any differences between the men and women or between the community dwelling and institutionalized groups.

The nature (positive or negative) and the strength of the association between important pairs of variables were determined with gamma correlation coefficients. Gamma correlation coefficients are specially valid for comparing paired observations with many ties (if two participants have the same score, their scores are tied) whereas both Pearson and Spearman correlation coefficients assume that there are no ties [240].

Factor analysis is an exploratory technique applied to a set of observed variables that seeks to find underlying subsets of variables from which the observed variables were generated. In order to define our FAIS (which incorporates the results of the seven functional tests), the principal axis method of factor analysis on the functional ability scores was used.

The Mann Whitney test was used to determine if there were any significant differences between those classified as high versus low risk of frailty based on the constructs of frailty described in section 4.2.2.4. Furthermore, a Chi-square analysis was performed to determine if there were significant differences for those classified as either high, moderate or low risk for frailty between the community dwelling and institutionalized groups.

Because of the number of multiple comparisons, the level of significance was conservatively assessed as $p<0.01$.

4.2.3. Sample size determination:

We estimated the sample size required to demonstrate differences in the various functional and self-reported measures, as well as, constructs of frailty between community dwelling and institutionalized older adults. Based on the study by Ho et al. [115], in which significant odds ratios were demonstrated between groups of community dwelling older adults who were at high and low risk of frailty (ranging from 2.9 for ADL to 7.7 for timed up and go), samples sizes required for 80% power at an alpha level of 0.05 would range from 23-61 individuals per group. Similarly, Chin A Paw et al. [147] compared groups of older adults defined as frail versus those who were not frail, and found significant differences in the proportion presenting with low performance in the following measures: ADL, walking speed and sit to stand. Based on these differences in proportion between frail and not frail older adults, we estimated that the sample size required at a similar statistical power and level of significance would range from 41 to 72 per group. Therefore, it is possible that for some measures, this sample may lack sufficient statistical power. This is elaborated in the discussion.

4.3. Results

4.3.1. Characteristics of sample

The health characteristics of the participants are described in Table 4.1. There were significant within group differences in median (Kruskal Wallis tests) for age, BMI, waist circumference, and lean body percentage. The men and women were similar in median age, however, those living in the communities were significantly younger than those living in institutions (Mann-Whitney tests). The institutionalized participants had significantly lower median BMI and waist circumference than the community dwelling counterparts.

For the total sample, 39% reported that their health was either very good or excellent, compared to 10% who reported their health as poor or very poor. However, only 33% felt that their health was better than their peers, while 42% thought their health "was not as good" as others the same age. Of those who regarded their health as excellent, 69% also felt it was better than their peers. Furthermore, of those who regarded their health as poor or very poor, 77% felt that they were worse than their peers.

4.3.2. Questionnaires (Self report)

4.3.2.1. DQ 98 Index score

The DQ 98 index score is a weighted sum of the scores for primary needs, ADL, care giving, mental health and skilled care. The median score for the sample was zero, with 52% of the participants regarded as independent (Table 4.2.). This suggests that most of the participants were independent and required little or no assistance for ADL (as listed in the DQ 98), received sufficient care, and had acceptable mental functioning as assessed by DQ 98.

However, the DQ 98 was unable to discriminate between those living in the community and those who were institutionalized.

The DQ 98 index score was significantly and positively correlated with the other questionnaire measures, including cognitive score, ADL (Bartell index) and IADL, (Table 4.3) and self-assessed health rating ($p<0.01$). The functional tests that were significantly associated with the DQ 98 included: dynamic balance, timed up and go, and normal gait speed (2.44m) (Table 4.4) for the total sample and also with maximal gait speed for the community dwelling group ($p<0.01$, Table 4.5). There were no other significant correlations.

4.3.2.2. ADL, IADL, Motor Disability and Cognitive Scores

There were no significant differences in self-reported disability for ADL and IADL between the institutionalized and community dwelling sample (Table 4.2).

The motor disability score was significantly associated with age, cognitive score, ADL, IADL, the DQ 98 index score and total weekly energy expenditure in the total sample ($p=0.002$; $p=0.004$; $p<0.0001$; $p<0.001$ and $p<0.001$, respectively) (Table 4.4). The same associations were found when analyzing the community dwelling groups separately. Only ADL and IADL scores were related to motor disability for the institutionalized sample (Table 4.5).

The median cognitive score for the total sample was 10, indicating that at least half of the participants were not cognitively impaired. However, cognitive function was significantly better in the community dwelling participants compared to the institutionalized group ($p<0.05$), as evidenced by lower scores (Table 4.2).

4.3.3. Functional Performance Tests

Tables 4.4, 4.5. and 4.6 show the relationship between the functional performance tests and age, self reported disability, cognitive function and weekly energy expenditure for the total sample, those who are community dwelling and the institutionalized participants, respectively.

The dynamic balance score was associated with age cognitive function, ADL, IADL, DQ 98 index score and weekly energy expenditure for the total sample (Table 4.4). The same relationships were found for community dwelling sample, except for cognitive function (Table 4.5).

The relationship between static balance and self-reported disability was not consistent between groups. For example, the static balance score was significantly associated with IADL for the total sample and community dwelling (Tables 4.4 and 4.6), but not with any of the variables for the institutionalized older adults. Likewise, weekly energy expenditure was significantly associated with the static balance score among those living in the community ($r=0.17$, $p<0.01$).

Functional reach was not related to any of the variables. For those living in the community, grip strength was significantly associated with age, ADL, weekly energy expenditure and lean body mass percentage.

The sit to stand test was weakly, but significantly associated with age, cognitive score, ADL, IADL and weekly energy expenditure for the total sample (Table 4.4). Conversely, this functional test was not associated with any of the self-reported scores among the institutionalized group (Table 4.5). For those living in the community, the time taken to complete five repetitions was associated with age, ADL, and IADL (Table 4.6).

The timed up and go test, walking speed (normal and fast pace) had similar relationships with the self-reported variables for the total sample and those living in the community. These tests were significantly related to ADL, IADL and weekly energy expenditure for the total sample (Table 4.3), and the community dwelling (Table 4.6) participants. Furthermore, the timed up and go and normal paced walking speed was related to age and the DQ 98 index score for the total sample (Table 4.4).

4.3.4. Functional Ability Index Score (FAIS)

4.3.4.1.Functional ability index score (FAIS): between group comparison

Table 4.2. describes the FAIS results, self-reported disability based on the questionnaire assessments and also reported weekly energy expenditure. The FAIS was able to discriminate between those living in the community and those who were institutionalized (Kruskall Wallis tests $p<0.001$). The community living participants had significantly greater functional ability than those living in institutions.

For the factor analysis, a weighted average of the seven individual functional scores contributed significantly (81%) to the total variation in the FAIS. The weights (score coefficients) were of similar magnitude, ranging between 1.8 and 2.8. Both the weighted (scores of the factor analysis) and the unweighted (sum of the eight functional ability scores) were calculated for each participant. These two scores were highly correlated ($r=0.99$), therefore, the functional ability index score was defined as the unweighted sum of the eight functional scores described in section 2. The possible scores were between 0 and 28 and the participants in our study had scores ranging between 3 and 27.

Furthermore, we described the participants as either at increased risk of frailty, moderate risk of frailty, and low risk of frailty, based on their functional scores. We arbitrarily classified our participants as at low risk of frailty if they scored more than 21, at moderate risk if they scored 8-

20 and at high risk if they scored less than 7. These values were based on the assumption that a score less seven indicates that the participant was either unable to perform most of the functional tests, or scored "1" for most of the tests. A score of 21 suggests that the participants scored an average of "3" for each of the seven functional tests. Significantly fewer of the community dwelling sample were classified as high risk for frailty, while a significantly fewer proportion of the institutionalized were classified as low risk of frailty, based on the Chi-squared analysis results (Figure 4.1).

4.3.4.2. FAIS and self reported disability, weekly energy expenditure and anthropometry

The FAIS, derived from our battery of tests, was significantly associated with cognitive, score, ADL, IADL, DQ 98 index score and weekly physical activity in the total sample (Table 4.3) and also for those living in the community (Table 4.4). Additional, significant relationships between the FAIS and ADL, IADL, DQ 98 and weekly physical activity were also present among the women (data not shown). None of the self reported variables from the questionnaires were associated with the FAIS for the institutionalized sample.

Calculating gamma correlation coefficients for the institutionalized and community dwelling groups separately, showed that the DQ 98 index score was not associated with the FAIS for the institutionalized subjects (data not shown). However, the FAIS was significantly associated with the DQ 98 index score in the total sample, and also in those living in the community (Table 4.8).

In order to form an idea of the nature of the association between DQ98 and FAIS, we classified each participant as DQ 98 independent, if their score was zero and as having high levels of functional ability if their FAIS score was more than 20. This resulted in 33% being independent or high levels of functional ability and 30% classified as dependant or low functional ability on both scores. The remaining 37% misclassified as either independent on the DQ 98 and as low functional ability on the FIAS, or as dependent in the DQ 98 and low risk on the FAIS.

Furthermore, the FAIS had a significant positive association with lean body mass percentage and weekly physical activity; and, understandably, a significant negative association with age (Table 4.6).

4.3.5. Comparison of constructs of frailty

4.3.5.1. Low physical activity and low BMI

For the first construct of frailty, where low PA was combined with low BMI (PA+BMI) (determined by lowest quartile), as described by Chin A Paw et al. [147], 10.4% of the total sample was classified as high risk for frailty and future disability (Figure 4.3). The Mann Whitney tests showed that frailty as defined by PA+BMI was able to discriminate between the high and low risk groups for ADL, IADL, DQ 98 score, BMI, lean body mass percentage, total weekly energy expenditure, dynamic balance, timed up and go tests and walking speed (Table 4.8). In addition, the FAIS was significantly higher among those classified at low risk for frailty (Table 4.8).

4.3.5.2. Cognitive Score

The second construct of frailty revealed that 32% of the participants scored more than 15 for cognitive function, placing them in the high-risk group for frailty and future disability (Figure 4.2). The low and high risk for frailty groups, based on the cognitive score, was significantly different for IADL, DQ 98, dynamic balance and functional reach (Table 4.8). There were no significant differences between the high and low risk groups for the ADL scores.

4.3.5.3. Constructs of frailty and functional ability

The FAIS was significantly higher among those regarded as frail using both the PA+BMI and cognitive score constructs for the total sample and also those living in the community (Table 4.8). In addition to the FAIS calculated in the present study, we compared the constructs of frailty to other functional scores adapted from Fried et al [239] and Guralnik et al [133]. The functional score adapted from Fried et al only included grip strength and gait velocity. The score calculated in Guralnik et al's [133] study was based on the Established Populations for Epidemiologic Studies of the Elderly (EPESE) guidelines, where performance in the sit to stand test, static (standing) balance and gait speed was summed.

The functional scores based on Fried et al [239] and the EPESE protocol [133], was significantly weaker for those classified as frail in the PA+BMI construct compared to those classified as "not frail" (Table 4.8). Similarly, for the cognitive function construct, both the Fired and EPESE scores were significantly different for between those who were frail or not frail (Table 4.8) for the total sample and community dwelling group.

None of the functional scores were significantly different for the institutionalized group for both the PA+BMI and cognitive score constructs.

4.4. Discussion

The main aims of this study were two-fold; firstly to compare self reported disability from the DQ 98 to a battery of functional performance tests (FAIS), and secondly, to compare two different constructs of frailty namely, low PA coupled with low BMI (PA+BMI), and impaired cognitive score. We found that the DQ 98 was unable to discriminate between those older adults living in the community and those who were institutionalized, whereas there were significant functional differences between these groups, as determined by the FAIS. Furthermore, the frailty construct of combined PA+BMI was able to distinguish between those classified as frail and not frail, better than the cognitive score alone.

4.4.1a. Relationship between FAIS and self reported disability and energy expenditure

A number of previous trials have used composite performance based scores as a determinant of ADL and IADL [117;133;231] dependence. Therefore, the first objective of our research study was to compare the FAIS, which is the sum of the seven functional performance scores, to self-report measures including the DQ 98 and also to ADL and IADL scores.

The first important finding in our study was that the FAIS was able to discriminate between the community dwelling and institutionalized subjects. Only 3.1% the community dwelling sample scored 7 or less for the FAIS, which indicates that they were either unable to perform all the tests, or they scored 1 for most of the tests, suggesting that they have the greatest functional performance difficulties compared to the rest of the sample. This is contrasted to the 17.24% of those living in institutions that scored 7 or less, indicating that a greater percentage of the institutionalized sample has more functional difficulties. Similarly, only two of the institutionalized sample scored more than 21, compared to 68 (25.5%) in the community dwelling group, further suggesting that the institutionalized older adults may be at increased risk of reduced functional ability, and are subsequently less independent than those living in the communities. (Figure 4.1).

A FAIS score of 21 suggests that the participants scored an average of 3, on the functional performance tests, and, therefore, places them in a higher functional ability category. The FAIS includes multiple measures of disability such as gait speed [136], measures of physical impairment (grip strength) [136] and physical measures (balance) [117]. Thus the FAIS represent the physical dimensions associated with dependence and disability, where those with higher scores were regarded as more independent.

Brown et al. found that lower scores for the Physical Performance Test (PPT), were associated with deficits in static and dynamic balance, decreased muscle strength, decreased range of motion, gait speed and sensory information from the periphery [117]. The adapted PPT included the sit to stand test, the Romberg balance test, and ability to perform tasks such as putting on and taking off a jacket as quickly as possible. Their findings [117] highlighted the concept that frailty is multidimensional and is a result of the accumulation of deficits in multiple domains. Therefore, the FAIS used in our study, which incorporates more than one domain associated with increased dependence and disability, may be useful in determining those who are at risk of frailty, or who are already frail.

Just over half the participants scored zero for the DQ 98, which is the highest obtainable score, and indicates that they are functionally independent. Conversely only 32% scored more than 20 for the FAIS, and none scored 28, which is the highest possible score for functional ability. Likewise Brach et al. [241] found that more than 60% of the women participating in their study scored 100 (highest possible score) for self-reported measures of function compared to 7% who achieved the highest possible score for the physical performance tests. Thus, our findings support that of Brach et al. [241] who concluded that performance based measures are more likely to detect functional impairments than self-report measures. The performance based measures may be particularly useful for those who have higher levels of functioning, as they may not recognize small deficits in performance, and subsequently report no difficulty in these tasks [241].

Winograd et al. reported that because performance based tests assess a given activity, they may not reflect the modifications an individual makes when performing day-to-day activities [231]. This finding is supported by Fried et al. who found that those who were able to perform a task, but had to modify the way in which it is performed, were at risk of becoming disabled at some point in the following 18 months [242]. Thus the participants in our trial may have reported that they are able to perform a task without any difficulty, resulting in higher ADL, IADL and DQ98 index scores. The same participants may have scored less than 21 for the FAIS, suggesting that they did not perform in the highest functioning category for each of the seven functional tests. As a result, there is inconsistency between reported and measured functional ability.

Fried and coworkers investigated whether those who reported that they modified their ability to walk half a mile and climbing 10 steps (pre clinical disability) due to health problems had decrement in physical performance [242]. Those who reported modification in the tasks had higher odds for decreased muscle strength, balance and chair stand times, compared to those who reported that they could walk half a mile or climb 10 steps without any modifications [242]. This modification in performing a task occurs before the individual is completely unable to perform the task, and may therefore account for some of the discrepancy between self-reported difficulties (DQ 98) and objective physical performance measures (functional ability score). Thus, self-report instruments such as the DQ 98 may be used in conjunction with physical performance measures to provide a more comprehensive assessment of the older adults level of disability [231;242].

The value of including functional performance measures with the DQ 98 questionnaire is also highlighted by the finding that there were no significant differences in the DQ 98 scores for the community dwelling and institutionalized groups. Thus, the DQ 98 on its own is unable to discriminate between these two groups. This is an important finding; since the DQ 98 was designed to assist health care workers to determine the urgency with which an older adult should be placed in institutionalized care. Therefore, the FAIS may provide an objective measure of functional ability, not only to assist with the decision for institutionalized care, but may also be able to evaluate the improvement or decrement in performance after institutionalization.

However, an important consideration for implementing the FAIS is the availability of resources and the training of staff. This is of particular importance to the institutions participating in our study, since they are located in previously disadvantaged communities and do not have the financial resources to attract and employ skilled staff [226]. As a result, may of these institutions are understaffed and under resourced. The FAIS comprises of seven functional performance tests and may therefore be too time consuming for the health worker to conduct on all prospective applicants in addition to routine testing of those already living in the institution. Although it might be possible to train community based workers and volunteers to administer the FAIS, thereby alleviating the health care workers' worklaod.

In order to determine whether a shorter battery of functional performance tests yields similar results to the FAIS, we compared the composite scores using variables described by Fried at al. [239] and the EPESE protocol described by Guralnik et al. [133] to the DQ 98 total score. We calculated an adapted score based on the factors associated with the phenotype of frailty described by Fried et al. (Fried score) by summing the gait speed and grip strength scores obtained by our subjects. The Fried scores would therefore have a maximum of 8, indicating greater functional independence, and a minimum of zero, indicating inability to perform both tests. The EPESE protocol includes tests of standing balance, 2.44m-gait speed and the sit to stand test [133]. The possible scores for the EPESE protocol, based on the scoring described in section 4.2.2.2, range from zero to 12, where a higher score indicates greater functional ability. Like the FAIS, both the Fried and ESPESE scores were significantly associated with the DQ 98 score for the total and community dwelling sample, but not for the institutionalized group.

The FAIS and Fried scores performed similarly, as both were associated with the DQ 98, r=-0.28 and r=-0.29 ($p<0.001$), respectively. However, the Fried score was not significantly different for the community dwelling participants compared to the institutionalized participants. The variables used to calculate the Fried score, gait speed and grip strength, were only two out of five criteria used to determine frailty in Fried et al's [239] study. Thus they were not intended to be used in isolation, but together with weight loss, exhaustion and habitual PA, to determine the presence to frailty in an individual [239].

Conversely, EPESE score was able to discriminate between community dwelling and institutionalized participants and also had a stronger association with the DQ 98, r=-0.33 ($p<0.001$) than the FAIS. Even though the EPESE score is only based on lower body function, it is a useful instrument for assessing functional ability, when related to the DQ 98. Based on this finding, we would therefore suggest the EPESE protocol in conjunction with the DQ 98, which is already in use, for a comprehensive assessment of urgency for institutionalized care and functional status, particularly if there is limited time available.

In addition to being associated with the DQ 98, the FAIS was associated with ADL (Bartell Index) and Lawton's IADL index in the total sample and also those living in the community. Higher functional performance is associated with increased independence in ADL and IADL, therefore the relationship between the functional ability score and self-reported disability were in the expected direction. Similarly, Winograd et al. compared the results of a "physical performance and mobility examination" (PPME) to self-reported ADL and IADL activities in men and women with impaired mobility [231]. The relationships between the PPME and ADL and IADL in their sample were comparable to ours, r=0.44 and r=0.31, versus r=0.52 and 0.47. Results between the present study and those of Winograd et al's [231] are similar, despite the fact that their participants reported impaired mobility (unable to walk more than 100 yards, or recent decline in mobility), whereas we included participants with and without impaired mobility.

Another important finding was that the FAIS was significantly associated with weekly energy expenditure, which was quantified using the YPAS questionnaire. Similarly Petrella and Cress reported that older adults with higher levels of functioning walked more often than those with low levels of functioning [243]. Rantanen et al.1999 also found a spiraling effect between motor disability, PA and muscle strength [125]. The relationship between these variables are described as follows: a decrease in motor disability results in decreased PA, which in turn results in decreased muscle strength, causing a further reduction in motor disability and subsequent lower levels of physical activity [125]. The significant association between lean body mass percentage and FAIS for the total sample and community dwelling group, may lend support to Rantanen's findings, since increased levels of PA will attenuate the loss of muscle mass associated with ageing.

Moreover, regular PA has previously been shown to be associated with a smaller decline in functional ability [52;225]. This relationship between habitual activity and subsequent disability was evident even when considering activities that were not sport based, such as walking, household activities and bicycling [52]. As a result, encouraging older adults to increase the habitual levels of physical activities may contribute to preserving their functional status [52] and also reduce the risk of mortality [225]. It is also encouraging that simple activities like walking and household tasks can play a role in maintaining functional independence.

Part 4.4.1.b: The relationship between the functional performance tests and self reported disability and weekly energy expenditure

ADL and IADL were associated with dynamic balance, timed up and go and 2.44m walk tests for both the total sample and those living in the community. These associations were not present for the institutionalized group, except for dynamic balance, which was related to both ADL and IADL. Similarly Judge et al. found that impaired balance function, slower gait speed and reduced grip strength was associated with increased IADL dependence in community dwelling men and women [114].

The protocol used for measuring static balance in our study was the same as that used for measuring balance in Judge's study [114]. Like Judge et al. [114] we also found that static balance performance was associated with IADL for our total sample and community dwelling groups. The lack of association between static balance and IADL in the institutionalized group may be due to the small sample size in this group. In addition, only 13% of those living in institutions could perform at least three of the four required stances, which was significantly less than the 56% in the community dwelling group who successfully performed all four stances. The participants in Judge et al's trial ranged in functional ability from those who were independent, to those who were regarded as frail, and the level of dependence in IADL for their sample was lower than representative population samples for the US [114]. Therefore, dynamic balance which was associated with ADL and IADL in both the community dwelling and institutionalized sample, may be a better measure of functional ability and level of independence, compared to static balance, when including older adults with various degrees of ability.

The timed up and go test was significantly associated with age, ADL, IADL, and DQ 98 index score for the total sample as well as those living in the community. Similar to the static balance tests, the timed up and go test was not associated with any of these variables for the institutionalized group. The lack of significance may in part be due to the small sample size and lack of variability for the institutionalized group. The community dwelling group performed the test significantly faster than the institutionalized group, although there were no significant differences for reported ADL and IADL scores between the two groups. As a result, the institutionalized sample may not have been sufficiently dependant, as measured by the self-report, although their functional test could be indicative of functional impairment. Bischoff et al. proposed that 12 seconds is the cut off time for the timed up and go test, whereby those taking longer to complete the test should receive intervention to improve mobility performance [238]. Nearly 45% of our community dwelling group completed the test in 12 seconds or less, compared to only 6% in the institutionalized. Based on Bischoff's suggested cut off point, this would mean that most of the institutionalized group would require interventions to improve their functional performance.

The field measures of upper and lower body muscle strength, namely, grip strength and the sit to stand tests, were significantly associated with ADL and IADL. Davis et al. reported similar results in community dwelling Japanese women, in which those with higher grip strength values reported fewer difficulties in ADL [244]. Although Davis et al. also found a relationship between sit to stand performance and ADL, grip strength was a stronger predictor of ADL performance than lower body strength [244]. In our study, the relationship between ADL and grip strength was also stronger than that with sit to stand performance, thereby corroborating Davis' findings. However, the relationship between IADL and grip strength was weaker than that with sit to stand performance. The difference in the association between upper and lower body strength with ADL and IADL, may be that the IADL activities require more strength, particularly lower body strength.

Furthermore, Davis et al. suggests that grip strength can be used as a marker of frailty and that improved strength could improve performance in task such as holding, picking up objects and more complex tasks such as feeding oneself [244]. Activities such as eating and holding onto an object such as a brush for grooming, is associated more closely with ADL, than IADL, which may further explain the stronger relationship between ADL and grip strength compared to sit to stand performance. Therefore both grip strength and a proxy for lower body strength such as the sit to stand test may provide a more inclusive assessment of the relationship between muscle strength and functional ability. The decline in upper body strength, may not parallel declines in lower body strength, and by measuring both measures, deficits could be identified and reduced with appropriate intervention.

Total weekly energy expenditure was significantly associated with all of the functional tests, except functional reach in the total sample and community dwelling group. Similarly, Brach et al. found that men and women who were physically active, performed better in the physical function tests than those who were sedentary [245]. In addition, increased levels of PA were associated with improved performance for the timed up and go test in Japanese women participating in the Hawaii Osteoporosis Study (HOS) [244]. PA has also been identified as a predictor of timed up and go performance in both institutionalized and community dwelling Swiss women [238]. The timed up and go test includes both strength (rising from a chair) and mobility (walking 6m) skills [238]. Consequently, Rantenen found that those with higher muscle strength, knee extensor and grip strength, reported higher levels of PA [125]. Thus increased PA could improve both muscle strength and agility resulting in improved functional performance. Improved functional performance in turn, could play a role in maintaining independence, and delaying the onset of disability. Therefore, encouraging both community dwelling and institutionalized older adults to participate in regular PA could assist in maintaining functional independence.

BMI was not associated with any of the performance-based measures in our study. This is in contrast to Davis et al. who found that women with lower BMI, reported fewer difficulties in ADL tasks [244] and also had better scores for the functional performance based tests than those with higher BMI's. Their participants were Japanese women, who had a lower mean BMI (23.4 ± 4.0) than our participants (31.4 ± 8.4). Furthermore, Harris [246] states that body weight is a determinant of muscle mass in sedentary elderly populations, where a higher weight is associated with higher lean mass. Thus, one would expect similar associations between functional performance and weight or BMI and lean mass. Visser et al. found that although leg muscle mass was associated with lower extremity functional performance in men, this association was only present in women after adjusting for BMI [247]. This led these authors to conclude that one should adjust for body fatness when exploring the relationship between lean mass and functional performance. Moreover, after adjusting for additional confounders, the relationship between leg muscle mass and lower extremity functional performance (gait speed and sit to stand test) was no longer significant [247].

Therefore, these simple functional performance based measures are associated with the DQ 98, ADL and IADL levels of independence. However, because frailty is multidimensional, we would suggest that the FAIS, EPESE or similar test battery be used to measure functional ability, instead of one or two isolated functional tests. These test batteries may provide a more comprehensive assessment of the individual's functional ability and may also play a role in determining current levels of disability, as well as predict future dependency [114]. In addition, health care workers can use these performance-based tests to identify deficits in functional ability and subsequently implement appropriate interventions.

4.4.3: Constructs of frailty

Frailty has been defined as a syndrome in which an individual has impaired function or deficiencies in more than one domain [116;238]. Thus the person who is unable to perform a specific ADL, but functions independently in other domains may not be classified as frail [116]. These domains include physical, nutritive, cognitive and sensory capabilities [116].

The proportion of individuals classified as frail based on low PA levels coupled with low BMI (PA+BMI), was similar to that described by Chin a Paw (10% and 6%, respectively). However a larger proportion of the participants were classified as frail using the cognitive construct (32%). Those classified as frail based on both these constructs had poorer IADL and DQ98 scores. Furthermore, the presence of frailty using these constructs was associated with weaker FAIS scores, as well as a weaker score based on grip strength and gait speed. However the PA+BMI construct was further associated with the EPESE score and also self reported ADL. Thus we would suggest that the PA+BMI construct is the preferred measure when attempting to classify those at high or low risk of frailty.

The associations between the PA+BMI construct and self reported disability and measured functional ability are paralleled by Chin a Paw, who described this construct of frailty [147]. Even though Chin a Paw's [147] participants were all male and community dwelling, their frail participants reported significantly more disabilities, and had a slower gait speed, and grip strength than those classified as "not frail". Therefore, this construct may be useful in determining which community dwelling men and women are at increased risk for frailty and future disability.

A more recent study by Fried et al. in which the researchers describe a phenotype of frailty, low PA was one of the five factors associated with frailty [239]. Two other characteristics of the frailty phenotype listed by Fried et al. were, slow gait speed, adjusted for height, and grip strength which was adjusted for body weight. Although we did not adjust for height and body weight when calculating a score for gait speed and grip strength respectively, we found a significant association between these two functional tests and both frailty construct, PA+BMI and cognitive score. Therefore, our findings support Fried et al. who found that there are physiological factors that may increase the risk of frailty and future disability [239]. Similarly, the FAIS and the EPESE scores were significantly different for the frail and not frail groups and also between the community dwelling and institutionalized groups using the PA+BMI construct. This would suggest that either the FAIS or EPESE scores could be used to determine the degree or risk of frailty.

Furthermore the PA+BMI construct was able to discriminate between performances in the dynamic balance, timed up and go, and gait speed tests. These findings are mirrored by those observed in a study conducted by Ho et al [115]. In Ho et al's investigation, community dwelling older adults were classified as high risk of frailty if they reported difficulty with more than one of five domains, which included physical performance, nutrition, cognitive function, vision and hearing. Their findings were revealed that those classified as high risk of frailty were 3.3 times more likely to have weaker dynamic balance performance, 7.7 times more likely to score below the mean for the timed up and go test [115]. The impaired performance for dynamic balance observed in our study as well as in Ho et al's [115] has important implications since poor balance has been related to increased risk of falls which in turn has been associated with increased disability and mortality.

Moreover, both our study and Ho et al's [115] did not find significantly weaker performance for the sit to stand test and grip strength among those classified as high risk for frailty. Ho et al. suggested that community dwelling older adults are able to maintain their independence if they maintain their muscle strength above a threshold, after which functional disability occurs. Thus, the sit to stand and grip strength tests may not be sensitive enough to measure small changes in muscle strength that could lead to future disability. In addition, the significant differences in one functional domain, such as balance, but not in another, such as grip strength, lend support to the use of a battery of functional performance tests, rather than one or two specific tests, when measuring functional impairment in older adults.

Despite the cognitive construct resulting in fewer significant differences for self reported disability and functional performance, compared to the PA+BMI construct, this measure may be a useful determinant of disability where PA and BMI cannot be measured. Impaired cognitive function has previously been associated with increased likelihood of developing or worsening disability and also poor health status [248]. Thus, this measure may contribute to determining IADL disability.

Because impaired cognitive function has been identified as one of the markers of frailty, this score may perhaps be combined with either habitual energy expenditure, or with the characteristics of the frailty phenotype described by Fried and colleagues [239].

The association between cognitive function, and in particular PA+BMI, with both self-report and functional measures, lends support to the theory that frailty is multidimensional. Consequently, tools that measure more than one domain of frailty should be encouraged. This is supported by Campbell and Buchner [112] who included grip strength, sit to stand performance, static balance, cognitive function and BMI as measures of the components of frailty, in addition to aerobic capacity and arm muscle area. Furthermore, we would encourage a battery of functional performance tests as this would enable health care workers to identify where improvements are required, e.g., upper body strength, or balance ability.

Based on the significant differences in the DQ 98 score for frailty classifications using both frailty constructs, this tool may be a useful measure of disability, particularly when used in conjunction with functional performance tests. Since this instrument was developed to assist health care workers in determining the urgency for institutionalized care, we propose that the DQ98 be used together with the FAIS. Because the FAIS was significantly different for the frail and not frail groups, as well as for the community dwelling and institutionalized groups, it is able to provide additional information on the individual's functional ability and degree of disability. However, if time and resources are do not permit the measurement for all seven of the tests included in the FAIS, the EPESE protocol would also be sufficient in order to provide addition information on functional ability in this community or setting

4.5. Summary

Self-reported mobility disability has previously been associated with mortality [249] and is therefore a valuable instrument. However, the functional performance tests are able to provide an objective measure of disability, and the tests use in our study can be conducted in the field, allowing for ease of administration. Therefore, the use of both the self-report and functional tests provide a comprehensive assessment of the older adult's ability in a number of tasks. These two methods of assessment should be both used since they compliment each other, rather than as a supplement for one or the other.

The FAIS was able to discriminate between those living in the community and those who were institutionalized, as well as between men and women. Furthermore, the FAIS was significantly associated with self reported difficulties derived from the ADL, IADL and DQ 98 questionnaires. Because the DQ 98 was unable to discriminate between the community dwelling and institutionalized groups, which was largely due to more than half of the total sample scoring zero, the FAIS may provide additional insight into the individual's degree of functional ability and impairment. In addition, the relationships between PA and the FAIS and the EPESE scores are important as they provide the evidence-base for promoting PA among older adults so as to improve both their health, and also to delay the onset of functional impairment.

The tests that contributed to the FAIS were included, among other factors, based on their ease of administration in the field. Each of the tests included can be completed in the participant's home, and from a public health perspective, may assist in extensive functional assessment of older adults. Furthermore, the repeatability of each of these functional performance measures has previously been reported [115;165], where r=0.68 for static balance [28]; r=0.83 for dynamic balance [250]; r=0.84 for the timed up and go [251]; grip strength [252] and sit to stand performance [29]. Although the functional performance tests for the FAIS are relatively easy to administer and require minimal equipment, the feasibility of training lay people would warrant further investigation. In South Africa, a large number of older adults volunteer their services to assist with the care of their fellow older adults [2]. If these volunteers can be successfully trained to administer the FAIS accurately, it may provide an avenue for extensive functional performance evaluations without adding to the health care worker's workload.

The PA+BMI construct of frailty was able to distinguish those at increased risk of frailty, as evidenced by the significant differences in scores for self-reported disability and the functional performance scores between those classified as frail versus those who were not frail. Thus PA+BMI, together with the functional performance tests may be able to provide further insight to individuals or groups who are at risk for frailty and disability. In addition the participants' BMI and habitual physical activity or energy expenditure and 6-Item cognitive score, will provide further insight in to the applicant's degree of independence and risk for frailty. These tools may therefore provide the health care worker with information on the domains of frailty that require intervention, for example, increase habitual PA. Once a weakness is identified in the older adult; an appropriate intervention can be implemented. Increasing PA in older adults may aid in increasing or maintaining functional performance, thereby delaying dependence and disability.

Moreover, the risk of mortality has been shown to be increased with disability [136], underscoring the importance of maintaining both the cognitive and physical function / independence of the older adult. Thus, future research in this community may include a longitudinal study design to investigate the relationship between baseline functional ability, both reported (questionnaire based) and measured (functional performance tests), on subsequent disability and mortality.

The importance of maintaining or increasing habitual levels of physical activity has been highlighted in this chapter. However, we have also found that the reported levels of PA are typically low in the communities represented in this dissertation. Therefore, these "at risk" groups are a likely target population for a PA intervention program. A limitation to such programs has previously been related to accessibility and affordability. Therefore, the following chapter investigated the effectiveness of a community based, low intensity intervention program in older adults from low socio economic groups.

Table 4.1: Basic characteristics of participants: Mean (Standard deviation)

Variable	Sample (n=221)		Community Dwelling (n=192)		Institutionalized (n=29)	
Age (years)	71.0	(7.8)	70.4	(7.5)	75.2	(8.4) ‡
BMI	31.4	(8.4)	32.0	(8.2)	27.1	(8.7) ‡
Waist (cm)	95.3	(17.7)	96.0	(17.4)	90.8	(19.7) ‡
Lean mass %	53.4	(9.6)	52.9	(9.4)	55.9	(10.6)
Systolic BP (mmHg)	144.1	(28.1)	145.2	(28.8)	137.1	(22.6)
Diastolic BP (mmHg)	79.6	(13.7)	80.4	(13.5)	74.7	(14.2)

‡: Community dwelling significantly different to institutionalized ($p<0.05$) (Mann Whitney)

Table 4.2: Functional ability and energy expenditure of participants: Median (25th; 75th percentile)

Variable	Sample (n=221)		Community Dwelling (n=192)		Institutionalized (n=29)	
Cognitive Score	10	(6; 18)	10	(4; 16)	14	(10; 24) ‡
ADL (Bartell)	14	(14; 16)	14	(14; 16)	14	(14; 16)
IADL (Lawton)	14	(9; 16)	15	(9.5; 16)	12	(8; 15)
DQ98 Index Score	0	(0; 3)	0	(0; 3)	1	(0; 2)
YPAS (kcal/wk)	1650	(630; 2843)	1674	(647; 3066)	1580	(609; 2308)
Functional Score (FAIS)	21	(13; 21)	21	(14; 22)	16	(11; 16) ‡
Motor Disability Score	9	(7; 12)	9	(7; 12)	8	(6; 12)
Static balance score	3	(0; 4)	3	(1; 4)	0	(0; 2) ‡
Dynamic balance score	1	(0; 2)	1	(0; 2)	1	(0; 2)
Functional Reach (cm)	92.7	(79.7; 102.0)	93.3	(81.2; 102.7)	83.5	(76.7; 96.3) ‡
Grip strength (kg)	18	(13; 22)	18	(14; 22)	15	(11; 20)
Sit to stand (sec)	18	(14; 23)	18	(14; 22)	23	(18; 26) ‡
Timed up and go (sec)	14	(11;19)	13	(10; 18)	17	(15; 20) ‡
2.4 m/sec $^{-1}$ (normal pace)	0.41	(0.27; 0.61)	0.49	(0.27; 0.61)	0.35	(0.27; 0.49)
2.4 m/sec $^{-1}$ (fast pace)	0.81	(0.41; 1.22)	0.81	(0.41; 1.22)	0.61	(0.41; 1.22)

‡: Community dwelling significantly different to institutionalized ($p<0.05$) (Mann Whitney)

Table 4.3: **Gamma correlation coefficient between functional ability index score (FAIS) and self reported disability and energy expenditure.**

	FAIS	ADL (Bartell)	IADL	DQ98 Index Score	YPAS (kcal/wk)
FAIS	1.00	0.52*	0.44*	-0.34*	0.35*
ADL (Bartell)	0.52*	1.00	0.56*	-0.57*	0.40*
IADL	0.44*	0.56*	1.00	-0.64*	0.51*
DQ98 Index Score	-0.34*	-0.57*	-0.64*	1.00	-0.43*
YPAS (kcal/wk)	0.35*	0.40*	0.511*	-0.43*	1.00

*: p<0.01

Table 4.4: **Gamma correlation coefficients for the functional performance tests and age, self reported disability, cognitive function and weekly energy expenditure for the total sample** (n=221)

	Age	Cognitive Score	ADL Bart	IADL	DQ98	YPAS EE
Static balance score	-0.11	-0.14	0.16	0.25*	-0.15	0.18*
Dynamic balance score	-0.22*	-0.25*	0.44*	0.41*	-0.33*	0.40*
Functional Reach (cm)	-0.10	-0.12	0.13	0.03	0.05	0.06
Grip strength (kg)	-0.16*	-0.09	0.22*	0.16*	-0.07	0.19*
Sit to stand (sec)	0.20*	0.14*	-0.16*	-0.21*	0.12	-0.15*
Timed up and go (sec)	0.18*	0.13*	-0.30*	-0.32*	0.29*	-0.17*
2.4 $m.sec^{-1}$ (normal pace)	-0.13*	-0.11	0.29*	0.40*	-0.33*	0.30*
2.4 $m.sec^{-1}$ (fast pace)	-0.08	-0.05	0.36*	0.38*	-0.34	0.26*
FAIS	-0.24*	-0.21*	-0.39*	0.40*	-0.28*	0.40*

*: p<0.01

Table 4.5: Gamma correlation coefficients for the functional performance tests and age, self reported disability, cognitive function and weekly energy expenditure for the community dwelling sample (n=191)

	Age	Cognitive Score	ADL Bart	IADL	DQ98	YPAS EE
Static balance score	-0.09	-0.06	0.15	0.20*	-0.15	0.17*
Dynamic balance score	-0.23*	-0.22	0.44	0.37*	-0.35*	0.41*
Functional Reach (cm)	-0.08	-0.08	0.13	-0.02	0.08	0.06
Grip strength (kg)	-0.16*	-0.05	0.23*	0.12	-0.05	0.17*
Sit to stand (sec)	0.21*	0.11	-0.16*	-0.18*	0.10	-0.13
Timed up and go (sec)	0.14*	0.09	-0.31*	-0.32*	0.31*	-0.15*
2.4 $m.sec^{-1}$ (normal pace)	-0.13	-0.10	0.29*	0.44*	-0.33*	0.30*
2.4 $m.sec^{-1}$ (fast pace)	-0.07	-0.03	0.35*	0.41*	-0.33*	0.26*
FAIS	-0.22*	-0.16*	0.40*	0.36*	-0.28*	0.42*

*: $p<0.01$

Table 4.6: Gamma correlation coefficients for the functional performance tests and age, self reported disability, cognitive function and weekly energy expenditure for those living in institutions (n=29)

	Age	Cognitive Score	ADL Bart	IADL	DQ98	YPAS EE
Static balance score	0.22	-0.06	0.51	0.29	-0.11	0.12
Dynamic balance score	0.01	-0.33	0.57*	0.66*	-0.26	0.20
Functional Reach (cm)	-0.07	-0.36	0.12	0.26	-0.17	0.08
Grip strength (kg)	-0.04	-0.35	0.19	0.38*	-0.28	0.32
Sit to stand (sec)	0.00	0.21	-0.10	-0.24	0.27	-0.20
Timed up and go (sec)	0.27	0.21	-0.22	-0.19	0.14	-0.20
2.4 $m.sec^{-1}$ (normal pace)	0.01	-0.13	0.36	0.21	-0.31	0.22
2.4 $m.sec^{-1}$ (fast pace)	-0.12	-0.18	0.44*	0.29	-0.40	0.21
FAIS	-0.09	-0.34	0.42	0.58*	-0.33	0.17

*: $p<0.01$

Table 4.7: Gamma correlation coefficient between functional ability index score (FAIS) and selected variables for total sample.

	Age	Cognitive Score	FAIS	BMI	Waist	Lean %
Age	1.00	0.20*	-0.23*	-0.13*	-0.13	0.009
Cognitive Score	0.20*	1.00	-0.23*	-0.17*	-0.16	0.14*
FAIS	-0.23*	-0.23*	1.00	0.009	0.09	0.14*
BMI	-0.13*	-0.17*	0.009	1.00	0.59	-0.64*
Waist	-0.13*	-0.16*	0.09	0.59*	1.00	-0.40*
Lean %	0.009*	0.14*	0.14*	-0.64*	-0.40	1.00

*: $p<0.01$

Table 4.8: Functional performance and self-report (questionnaire) scores for those classified as either "frail" or "not frail" based on Low PA+BMI and Cognitive score. Median (25th; 75th percentile)

	PA+BMI				Cognitive > 15			
	Frail		Not Frail		Frail		Not Frail	
Composite Functional Scores								
FAIS	12	(9; 16)	19	(14; 21) ‡	16	(11; 19)	19	(14; 22) *
Functional score (Fried et al) [239]	4	(2; 6)	5	(4; 6) ‡	5	(3; 6)	5	(4; 7) *
Functional score (EPESE)	6	(4; 7)	8	(6; 10) ‡	8	(6; 9)	8	(6.5; 10)
Individual Functional Performance Scores								
Static Balance	2	(0; 4)	3	(1; 4)	2	(0; 4)	3	(0.5; 4)
Dynamic Balance	0	(0; 1)	1	(0; 2)	0.50	(0; 1)	2	(0; 2) *
Sit to Stand (secs)	21	(17; 26)	18	(14; 23)	20	(15; 25)	18	(14; 22)
Timed Up and Go (secs)	19	(13; 26)	14	(10; 18)	16	(11; 20)	14	(10; 18)
Grip Strength (R)	13	(8; 20)	18	(14; 22)	17	(11; 22)	18	(15; 22)
Gait Speed (m/sec)	0.29	(0.14; 0.49)	14	(0.31; 0.61)	0.35	(0.27; 0.49)	0.49	(0.31; 0.61)
Self Report Scores								
ADL (Bartell)	13	(12; 14)	14	(14; 16) ‡	14	(13; 16)	14	(14; 16)
IADL	6	(4; 10)	15	(11; 16) ‡	13	(6; 16)	15	(10; 16) *
DQ98 Index Score	4	(1; 8)	0	(0; 2) ‡	2	(0; 5)	0	(0; 2) *
Cognitive Score	14	(10; 18)	10	(6; 17)	21	(18; 25)	8	(4; 10) *
Motor Disability Score	8	(7; 10)	10	(7; 12)	9	(6; 11)	9	(7; 12)
YPAS (kcal/wk)	350	(175; 490)	1890	(923; 3148) ‡	1351	(420; 2823)	1760	(787; 3213)

‡: Significant difference between those classified as frail compared to those classified as not frail based on the PA+BMI construct
*: Significant difference between those classified as frail compared to those classified as not frail based on the cognitive score construct
PA+BMI construct is calculated based on quartile values, where those in the lowest quartile for both physical activity and BMI are classified as frail.

Figure 4.1: Percentage of participants classified as high, medium and low risk for frailty based on FAIS scores

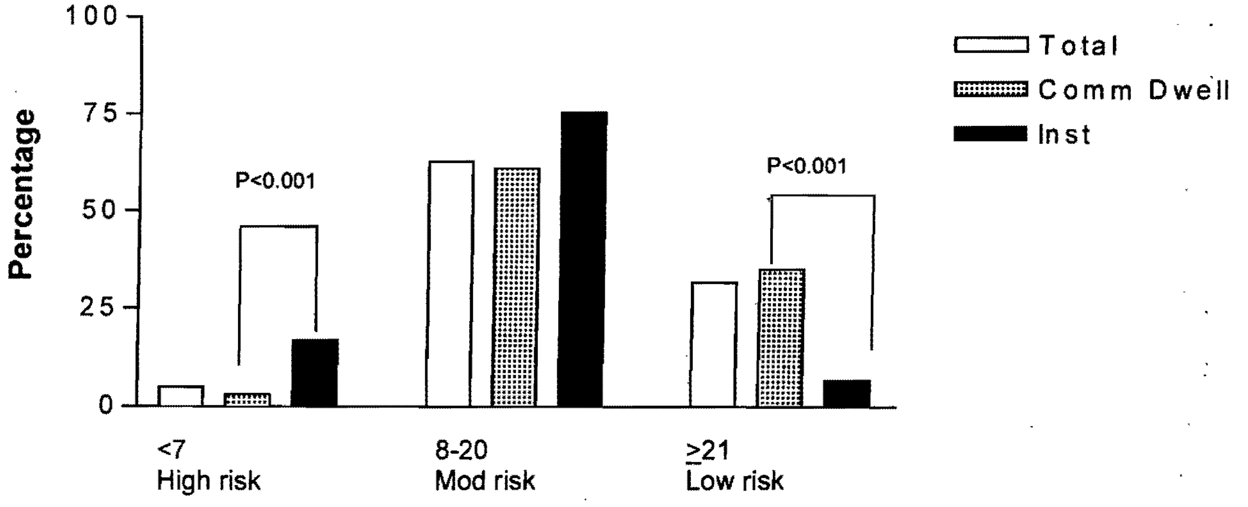
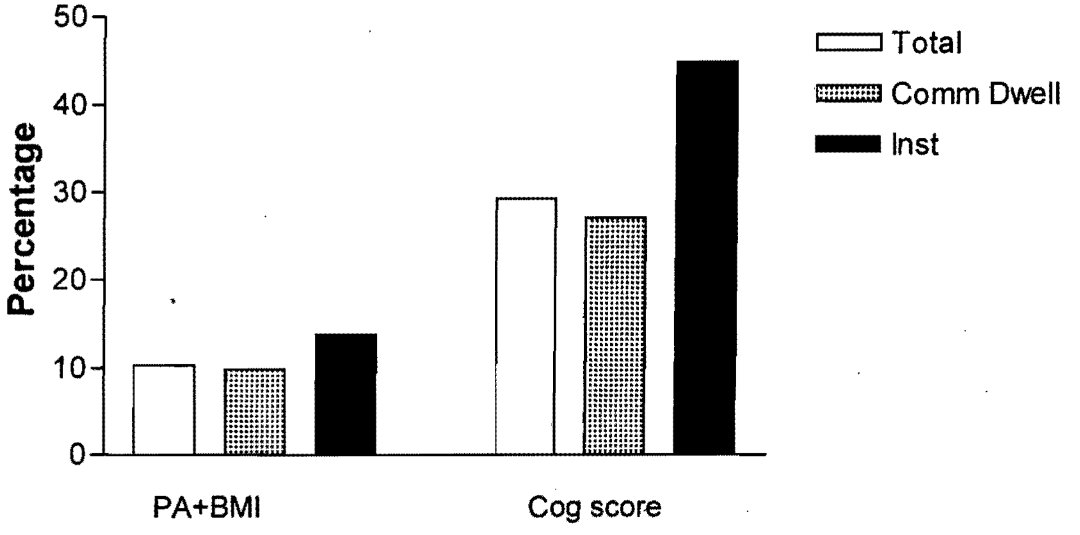


Figure 4.2: Percentage of participants classified as high risk for frailty using two definitions (PA+BMI and Cognitive score)



Footnote:

PA+BMI construct is calculated based on quartile values, where those in the lowest quartile for both physical activity and BMI are classified as frail.

CHAPTER 5

EFFECTIVENESS OF A COMMUNITY BASED LOW INTENSITY EXERCISE PROGRAM FOR OLDER ADULTS

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5.1. Introduction

The results of chapter four highlight the role of PA in maintaining functional performance in tests such as the sit to stand and dynamic balance tests. However, the current levels of PA among those participating in the studies described in chapters one to four are very low. PA intervention programs have been previously shown to improve health and functional measures. For example, Binder and colleagues found that a nine-month low intensity exercise program resulted in improved scores for the Physical Performance Test (PPT), VO_2 max and also reduced difficulties in ADL tasks [253].

Physical activity has also been associated with reduced risk for chronic diseases of lifestyle such as coronary artery disease and hypertension. Individuals from low socio economic groups, with low levels of education, being female gender, minority status and older adults are regarded as those who are most likely to be sedentary [203]. Therefore, the older adults from lower socio economic groups and also from the population groups who were previously discriminated against by the Apartheid government may potentially have the most to gain from a community based physical activity intervention program.

South Africa has the highest proportion of older persons in the Southern African region with nearly 7% of the population over the age of 60 years in 1997 [76]. In 1990, at least 92% of previously disadvantaged older South Africans had no medical insurance, yet 90% had annual medical expenses [1], which highlights the burden of disease in communities of low socio economic status. As communities move rapidly through the epidemiological transition, the burden of disease shifts to older adults and the often preventable, chronic diseases of lifestyle [3]. There is consistent evidence that increased levels of habitual PA, and specifically, exercise intervention, may improve quality of life and functional independence, as well as reducing the risk of falls in older persons [48;52;244;254;255]. Even in older adults, regular PA has been associated with an overall reduction in morbidity and mortality [256].

Ageing causes a progressive impairment in cardiac, pulmonary, musculoskeletal, and metabolic endocrine function, that may be attenuated by PA [257;258]. Indeed it has been shown that four out of every ten persons over the age of 65 years, have some chronic disorder that may result in functional limitation [259]. Furthermore, declines in strength may explain, in part, some mobility impairment and a loss of physical independence in the older person [260].

Despite evidence that PA can preserve mobility in older adults, there is a trend for activity levels to decline with increasing age. The decline in activity levels is more pronounced in women, low-income groups and in persons with low education levels [261]. The success of exercise interventions targeting these "at-risk" groups may, therefore, be limited by factors such as lack of facilities and resources, poor accessibility, as well as lack of education or awareness regarding the potential benefits thereof.

Although the benefits of exercise intervention in older adults have previously been documented in developed countries, there is little data available on the effectiveness of exercise programs in developing communities. Community-based exercise interventions may be more "culturally-sensitive" than institutionalized exercise programs, and low intensity regular activity may encourage more independent living, which could delay the need for institutionalized health care. The aim of the present study was to determine the effectiveness of a 20-week exercise program conducted at community centers in producing beneficial changes in physical functioning, muscle strength and endurance, balance, habitual levels of physical activity, self perceived health status and blood pressure of older adults. We hypothesized that those participating in the exercise intervention would experience significant improvements in fitness parameters such as muscle strength and balance in addition to health parameters such as blood pressure.

5.2. Method

5.2.1. Study Design:

Subjects were drawn from three different community centers (state-subsidized luncheon and social clubs) to participate in a quasi-experimental community-based, intervention trial. All the subjects signed a written, informed consent after the details of the study were explained. Two centers were randomly allocated to the intervention group (EX1 and EX2) and one to the control group (CTL) for 20 weeks. All groups met twice weekly. Measurements were taken at baseline (pre) after randomization and after 10 and 20 weeks of intervention. All subjects were community-dwelling and were selected from similarly matched communities with regard to socio-economic status and infrastructure. The same researcher conducted all the measurements and conducted the exercise session for the intervention groups, as well as the relaxation and social sessions for the control group.

5.2.2. Participants

The strategies for selecting the groups to participate in the research study were based on geographical location. Groups were of the same socio demographic and economic status, were of mixed racial ancestry, and were situated far enough from each other to prevent contamination between the two exercise groups and control groups. The allocation of the luncheon clubs to either the control or exercise intervention, was done by drawing numbers from a hat, where numbers one and two were exercise groups and number three the control. The participants in both the intervention and control groups were blinded to the investigator's hypothesis. Furthermore, those in the control group were not aware that they were receiving a placebo intervention.

Community dwelling females, aged 60 years and older, who had been inactive for at least three months prior to the study (determined by questionnaire), were eligible for inclusion. There was no physician screening or clearance prior to participation in the research study. Therefore, participants were excluded if they had uncontrolled hypertension (blood pressure more than 160/95 on entry and not on medication) or known heart disease (self reported), or if they were unable to care for themselves (evaluated by measuring the level of assistance required for activities of daily living).

5.2.2.1. Intervention group.

The intervention group participated in low intensity exercise, twice weekly for 20 weeks. An attendance register was administered at each session to assess adherence.

The exercises were designed so that they could be completed in a seated position, except those for balance training or proprioception, which were done standing. Each exercise session was 45-50 minutes in duration and remained at a low intensity from weeks one to twenty. Participants enjoyed a 30-second break after every set of three until week 11, after which they exercised continuously for 50 minutes. The 10-minute warm up comprised of seated marching, varying in tempo, and involving both single and double leg movement. In addition, participants clapped or clicked their fingers while marching legs. The 35 minutes of exercise that followed the warm up comprised of both upper and lower body exercises. Examples of lower body exercises include, straight leg raises, knee raises, alphabet tracing, heel raises and ankle circles, which were all performed without the use of dumbbells or weights. Plastic soft drink bottles (500ml), partially filled with sand were used as weights for upper body exercises from week 11. The upper body exercises included biceps curls, front and side arm raises, single arm shoulder press and chest press. Two sets of 10-15 repetitions were performed for each exercise. Seated marching of approximately two minutes was performed after every three exercises. The 10-minute cool down consisted of slow marching and stretches. Proprioception exercises, which included supported, single leg balancing with the eyes open, and then closed, were performed as part of the cool down in the standing position.

After the 20-week intervention, four volunteers from each group were trained as leaders. The training included the theory and practical aspects of leading an exercise session, and also information on chronic disease of lifestyle. Once the leaders completed the training, they became responsible for the continued implementation of the exercise program.

5.2.2.2. Control Group:

The control group met twice weekly for 20 weeks and participated in seated relaxation classes or arts and crafts and sing-along activities that were one hour in duration.

5.2.2.3. Measurements

5.2.2.3.1. Questionnaires:

Questionnaires evaluating the level of assistance needed to complete ADL (eating, dressing, bathing, toileting and weight transference from a bed to a chair required) and IADL (food preparation, shopping, climbing 10 steps, lifting heavy objects and using public transport) [233] were administered. Composite scores were calculated separately for ADL and IADL with a low score indicating greater functional independence.

Habitual physical activity levels were measured using the validated Yale Physical Activity Survey (YPAS) for older adults [19] described in chapter 2, section 2.2.3.1.

A questionnaire was administered to gain information on socio-demographic and socio-economic status. Self-reported health status was assessed using a five-item scale [262].

5.2.2.4. Assessment of muscle strength, cardiovascular endurance, gait, balance and functional capacity:

5.2.2.4.1. Lower body Muscle Strength Test:

Lower body muscle strength was assessed using the adapted sit-to-stand test, in which the maximum number of sit-to-stand repetitions, which could be completed by a subject in 10 seconds, was recorded [124;172].

5.2.2.4.2. Grip Strength Test:

Grip strength was determined using a hand held dynamometer and measured in kg of isometric force. The protocol used is the same as that described in chapter 4, section, 4.2.2.6.

5.2.2.4.3. Cardiovascular endurance Test:

Subjects were asked to walk as far as possible, within a six minute time period [263]. An 80m square was marked (20m per side) and participants were instructed to walk as far as possible during the 6-minute period. The total distance covered was recorded in meters. The test was repeated at the same time of day at both 10 and 20 weeks.

5.2.2.4.4. Gait Quality Test:

Functional gait capacity was assessed using a 20m-walk test [126], in which the time taken to complete the distance and the number of steps taken while walking at habitual velocity, were recorded.

5.2.2.4.5. Static Balance Test:

Static balance was assessed by asking the subject to stand for as long as possible (a maximum of 30 seconds) under the following stance conditions; comfortable stance (feet shoulder width apart), narrow stance (feet together) and tandem stance with the left then right foot leading. If the subject failed to maintain the stance for 30 seconds, a second attempt was allowed and the average duration of the two attempts was recorded [231].

5.2.2.4.6. Dynamic Balance Test:

The amount of time taken to walk 10 m using the tandem gait, (walking heel to toe), was used as a measure dynamic balance [264].

5.2.2.5. Anthropometric Measurements:

Height (to the nearest 0.5cm) and mass (to the nearest 0.5kg) were measured. In addition, girth measurements (mid arm circumference, waist, bitrochanteric, mid thigh) were obtained. Waist to hip ratio and body mass index (kg/m^2, BMI) were calculated.

5.2.2.5.4. Blood pressure:

Three measurements of systolic and diastolic blood pressure, taken at least one minute apart, were recorded for each subject using a calibrated standard mercury sphygmomanometer. The measurements were recorded in the morning and subjects were seated quietly for at least 10 minutes before the first reading was taken. The lowest diastolic value, with the corresponding systolic value, was included in the analysis. A subset of participants were identified as those being hypertensive at baseline BP > 140/90 mmHg).

5.2.2.5.5. Statistical Analysis:

STATISTICA software package was used for Windows 98 was used for all the analyses (Stasoft, Inc. 184-199, Tulsa OK, USA). Descriptive statistics were performed for the exercise and control groups separately. One-way analyses of variance were used to detect significant demographic differences between the exercise and control groups. Frequency tables were used to determine the percentage of subjects who were hypertensive, smoked and for the self perceived health rating scale. Chi^2 analysis was performed to determine significant differences between the groups for non-parametric variables.

Analyses of variance for repeated measures (ANOVA) were used to determine differences between groups for changes in continuous variables at pre, 10 – 20-weeks, after co varying for percentage attendance. Tukey's HSD post hoc analysis was performed where significant differences were found. Significant differences in baseline variables were entered as covariates in the ANOVA analyses; however this did not change the results. Thus results are reported after co varying for only attendance and BMI.

Additional ANOVA tests were performed for systolic and diastolic blood pressure, where the difference between hypertensive and non-hypertensive subjects in the EX1, EX2 and CTL groups were compared. Percentage attendance and BMI were used as covariates in this analysis. In addition, the Pearson's product-moment correlation was performed to determine if a dose response relationship exists between a decrease in blood pressure and the number of intervention sessions attended. Furthermore, the delta value from baseline to 10 weeks and from baseline to 20 weeks was calculated, which were the dependant variables in an additional ANCOVA test, where EX1, EX2 and CTL were categorical variables and baseline systolic blood pressure was the continuous variable.

The level of significance for all statistical analyses was alpha < 0.05.

5.3. Results

5.3.1. Subject characteristics

Subjects' morphological characteristics are presented in Table 5.1. Groups were well matched in terms of age, mass and body fat content. Groups were also not different in terms of employment and years of education. Most of the subjects were receiving a state pension. In addition, 16% of EX2 and 8% of EX1 and CTL received a private pension.

There was no significant difference in the prevalence of hypertension between the groups. Forty percent of EX1, 48% of EX2 and 52% of CTL were hypertensive. EX1 had the greatest proportion of subjects with Type 2 diabetes mellitus (23% versus 7% in EX2 and 5% in CTL). There were no significant differences in self-rated health status and health concerns between the two groups at baseline and after 20 weeks. Furthermore, average attendance to either the exercise or control intervention was not significantly different between the three groups (EX1 = 65%: EX2= 76%; CTL = 69%) and no adverse events related to the intervention were reported.

Despite randomization, significant differences between the groups were noted prior to intervention in tandem (EX1 vs. EX2; $p< 0.03$) and dynamic balance (EX1 vs. Ex2; EX2 vs. CTL, EX2 vs. CTL; $p< 0.02$), dominant grip strength (EX1 vs. Ex2, EX2 vs. CTL; $p=0.012$), sit to stand repetitions (EX1 vs. Ex2; $p<0.04$) and habitual activity levels (Ex1 vs. Ex2, EX2 vs. CTL; $p<0.04$). EX1 generally had a lower initial functional status and were more sedentary than members of EX2 and CTL. There were no other significant differences between groups prior to intervention.

5.3.2. Changes in functional physiology, functional limitations and disability in response to intervention

Dynamic balance improved significantly from baseline in the EX1 and EX2 groups (ANOVA group by time effect: $p = 0.013$). The post hoc analysis revealed significant improvements from baseline to (75.1 ± 31.5 sec) to 20 weeks (55.3 ± 13.6 sec; $p=0.005$) in EX1 and EX2 (53.3 ± 17.0 at baseline to 37.0 ± 10.4 at 20 weeks) (Figure 5.1). There were no significant changes in the CTL group, even after covarying for percentage adherence and baseline values (53.7 ± 29.8 to 52.1 ± 16.4 sec). There was no significant group or time effect for the analysis of variance (ANOVA) analyses.

The exercise groups also significantly increased the number of repetitions for the sit to stand test in response to the training program, as evidenced by the significant group by time effect for the ANCOVA analysis (p= 0.003). EX1 showed a significant improvement only after 20 weeks (P<0.0001). EX2 however, showed significant changes at each testing phase (Figure 5.2). The control group did not show improvements in this variable. The sit to stand test is a proxy measure, which incorporates the physiological capacities of lower extremity muscle power and balance.

Both the EX1 and CTL groups showed significant improvements in static balance (tandem stance, p<0.04), while EX2 and CTL improved the distance covered for the 6-minute walk test after 20 weeks (p<0.016). EX1 improved for the 20m-walk test (p<0.001), however there were no improvements for EX2 and CTL. However, the ANOVA showed no significant group, time or group by time effects for these variables.

There was also no significant improvement in grip strength after 20 weeks of the exercise intervention. In addition, no significant changes were observed for ADL and IADL following intervention.

5.3.3. Self reported energy expenditure changes after intervention:

Self-reported exercise related energy expenditure increased in EX1 and EX2 baseline to 20 weeks, compared to the CTL (ANOVA group by time effect: p=0.0008) (Figure 5.3b). There was, however, no consistent change in total weekly energy expenditure, a composite score of work, yard, care-giving, recreation and exercise activities.

5.3.4. Changes in blood pressure after the intervention:

Systolic blood pressure declined significantly from baseline to 20 weeks in both EX1 and EX2, compared to CTL group (group by time effect: p=0.013, Table 5.3). A dose response relationship between changes in systolic blood pressure and number of intervention sessions attended was not present. Furthermore, the ANOVA comparing the delta values from baseline to 10 weeks and baseline to 20 weeks, with baseline systolic blood pressure as the continuous variable, showed significant group by time effect (p=0.007). The post hoc analysis revealed that the delta value from baseline to 10 weeks was significantly different to the delta baseline to 20weeks value, in EX2 (p=0.0128). There were, no significant changes in diastolic blood pressure between groups or in response to intervention.

In a sub-sample of subjects who were previously diagnosed as hypertensive (n=38, Table 5.1), there was a significant (P=0.005) decline in systolic blood pressure in the combined EX groups (Table 5.4). Conversely, systolic blood pressure in hypertensive patients from the control group increased slightly over 20 weeks.

BMI decreased significantly in EX1 from 10-20 wks and pre to 20 weeks, however changes in BMI in EX2 and CTL groups were not significant.

5.4. Discussion

In the present study, we demonstrated that 20 weeks of low intensity seated exercise intervention significantly improved dynamic balance in community dwelling older adults. This is especially important, as falls are one of the determinants of increased morbidity and reduced functional independence in older adults [260]. Poor balance has been identified as a contributing factor to falls, [229] as well as influencing quality of gait [124]. An improvement in balance may reduce the risk of falling and thus indirectly improve the quality of life of the older adult. Similarly, Taggart found that three months of twice weekly Tai Chi exercise improved balance and functional mobility significantly in older women [265].

The exercise intervention, per se, did not have a significant effect on static balance, as measured by the tandem stance. This may be due in part, to the fact that the subjects in our trial were already functionally independent at baseline and a more sensitive measure may have been needed to yield improvements in static balance performance. Indeed 78% of subjects managed to balance the entire 30 sec at the outset.

The second important finding was that the exercise intervention was associated with increased repetitions achieved in the sit-to-stand test, which serves as a proxy measure for lower extremity muscle power and balance. This significant improvement occurred in both EX1 and EX2 even though the exercises were performed in a seated position. Taaffe et al. observed the effects of once, twice and three times weekly resistance training on strength in older adults [266]. Subjects in both groups demonstrated a significant decrease in the time required to rise from a chair five times, suggesting increased lower extremity muscle power and function. Similarly, Rogers et al. [267] demonstrated that chair based training, using elastic bands and dumbbells, improved lower body strength (also measured by chair stands), significantly in older African American women [268]. Muscle weakening has been associated with decreased gait speed and a progressive decrease in the amount of load that can be lifted by the muscle [256]. Furthermore, decreased lower body muscle function has been associated with poor health status and mortality [138]. The maintenance or improvement in muscle strength may assist in maintaining functional ability in activities of daily living in the elderly.

Davis et al. investigated the relationship between strength and performance-based tests and ADL in 704 older women (mean age 74 years, range 55 – 93 years) [244]. The stronger women encountered fewer difficulties with ADL. The improvement or maintenance of lower body strength may impact positively on balance and functional capacity, and may thus reduce the incidence of falls and subsequent loss of functional independence in older adults. Subjects in the present study had a relatively high initial functional status and were able to carry out most ADL with little difficulty, which probably also explains the lack of improvements in ADL and IADL following intervention.

Another important outcome of this study was that 20 weeks of twice weekly, community-based exercise intervention of low-intensity, was effective in significantly lowering systolic blood pressure in a group of older individuals. The impact of exercise intervention on systolic blood pressure was similar in magnitude to that of anti-hypertensive medication. A 4.6 mmHg reduction in systolic blood pressure has been observed in response to anti-hypertensive medications in similar populations of older adults [258;269]. These individuals represent communities who previously have been shown to have a high prevalence of hypertension (46% men and 73% in women) [75], and who are socio-economically disadvantaged, with limited access to health care.

Systolic blood pressure declined from 148 ± 13 to 144 ± 13 mmHg in the EX1 group and from 143 ± 14 to 137 ± 15 mmHg in the EX2 group, in contrast to the control group, in which systolic blood pressure actually rose over the 20-week period. These changes are comparable to previous studies of exercise intervention in older adults [170;269;270]. Morey et al. demonstrated a mean decrease in systolic blood pressure of 5.8 ± 2.5mm Hg in a group of older adults, exercising three times weekly for 90 minutes per session [269]. Although the training volume in their study was considerably greater compared to our study, the changes in blood pressure induced by the two studies were similar in magnitude. In addition, the improvements in systolic blood pressure is similar to that described in a meta analysis conducted by Whelton et al. where aerobic exercise significantly decreased systolic blood pressure by 3.84; 95% CI 3.35;1.81 mmHg in older adults [270].

Similarly, Young et al. demonstrated that both aerobic exercise and T'ai Chi (low intensity exercise) training significantly reduced blood pressure in older adults by 8.4 ± 1.6 and 7.0 ± 1.6 mmHg, respectively [82]. These authors concluded that programs of either moderate aerobic activity or low intensity exercise might have similar effects on blood pressure reduction in previously sedentary older adults.

Furthermore, systolic blood pressure decreased significantly (6mmHg ± 13.6) in subjects from EX (EX1 + EX2) who had previously been diagnosed as hypertensive by their doctors, compared to no improvement in the CTL group. This finding is especially important as the study sample represents communities that have been also been described as having poor knowledge of the consequences of uncontrolled hypertension and, as a result, have low levels of compliance with anti-hypertensive medication in subjects requiring treatment [7]. The reported level of medication compliance in Steyn et al. was only 40% [7], and was less than the mean percentage attendance at the intervention sites (EX1= 65%; EX2 = 76%; CTL = 69%). In addition, the mean BMI and waist circumference values for the subjects in our study were at levels associated with elevated risk if cardiovascular diseases, diabetes and mortality, which further emphasizes the beneficial effects of controlling blood pressure in this population group [20;271].

Other studies have demonstrated even more marked decreases in systolic blood pressure with exercise training in older adults. Motoyama et al measured the effect of nine months of exercise training in a population of hypertensive older (75 years) adults [83]. A decrease in systolic blood pressure in the exercise group of approximately 15 mmHg from baseline to three months, and 17 mmHg from baseline to nine months was demonstrated [83]. The greater frequency (6 times weekly vs. twice weekly) and the longer duration of the former study, (9 months vs. 5 months) of the exercise intervention in Motoyama's study, compared to the present study, probably explains the larger blood pressure-lowering effect.

The importance of our finding in the Mixed Racial Ancestry group of older South Africans is of importance, since this group has previously been identified to have a high prevalence of hypertension, which is poorly controlled [20]. Similarly, non Hispanic Blacks have higher rates of hypertension and lower PA levels compared to other ethnic groups in the United States [272]. The non Hispanic Blacks who participated in regular PA had lower odds ratio compared to those who were sedentary (OR 0.7) [272]. For the South African sample [273], historical or past occupational PA, but not present activity, was associated with lower systolic blood pressure in this population. Although historical PA was not assessed in our study, the results of Chartlon et al [9;20] together with those of the current study emphasizes the importance of both historical activity, and PA intervention for this ethnic group [20]. Furthermore, in a meta analysis conducted by Whelton et al., 2000 [270], it was reported that Blacks had a greater reductions in systolic blood pressure than Caucasians, in response to aerobic training.

The reported habitual weekly energy expenditure of our sample at baseline was less than half of that reported for older North Americans using the same questionnaire [19]. Total exercise-related energy expenditure increased significantly in the exercise intervention groups, which may be largely due to the twice-weekly exercise sessions, since energy expenditure did not increase in the other activity domains. These improvements in weekly energy expenditure are of particular importance to the older adult, since PA may attenuate the decline in mobility that is otherwise associated with ageing [52].

The twice-weekly exercise intervention did not result in significant improvements in upper body strength, despite the inclusion of upper and lower body strengthening exercises in the program. Similarly McRae et al failed to show improvements in handgrip strength in nursing home residents after 12 weeks of daily walking [170]. However, McMurdo et al. observed improvements in grip strength in nursing home residents after 7 months of seated exercise [274]. Maintenance of upper body strength is of importance to the older adult, as handgrip strength has been found to be a strong predictor of mortality in older Mexican Americans [138]. It is probable that greater improvements may have been observed in our study if the exercise sessions were of a higher intensity/ used higher force and also if the subjects had had a lower initial functional status. Furthermore, testing grip strength using the hand held dynamometer may not have tested all the muscle groups (arm and shoulder) that were trained during the exercise intervention.

Gait velocity, measured by walk time over 20m, improved significantly in all three groups. This suggests that the 20m-walk test may not be sensitive enough for field-testing when measuring the velocity and quality of gait in a group of older adults with high initial functional status. In a study conducted by Lord et al. exercising subjects improved significantly in walking speed, cadence and stride length after 22 weeks of exercise, compared to no improvement in the control groups [264]. These subjects were older than the current study sample (mean age 71.1 years versus 68 years). In addition, quality of gait was measured using Kistler 9281B11 load platform that is more sensitive than the 20m test used in the present study. Similarly, the distance covered in the 6-minute walk test improved significantly in both groups. These improvements may have also been due to a learning effect.

The limitations to this study are that the communities rather than subjects were randomized to treatment and the study was conducted in a single blind manner, although efforts were made to minimize bias on re-assessment. Groups were assigned to either intervention or control, rather than individuals, to reduce the possibility of contamination, as subjects from the CTL and EX groups lived in close proximity to each other. Thus the analyses at individual rather than center level might be an additional limitation.

5.5. Summary

In summary, a low intensity exercise program in a community setting has been shown to be effective in improving dynamic balance and sit to stand performance which is a proxy for lower body muscle strength in free-living older adults. Reductions in systolic blood pressure for EX1 and EX2, as well as the sub sample who were hyptertensive at baseline, produced by the exercise intervention were similar in magnitude to studies in which anti-hypertensive medication was administered. Low intensity programs of this nature may be sustainable if volunteer workers within communities are trained to conduct the exercise sessions. In addition, the risk of injury may be reduced because participants are seated, and the low intensity reduces the likelihood that a cardiac episode will develop during the exercise session. Research investigating the long-term effects of regular low intensity exercise in both institutionalized and community dwelling older adults, particularly among those who are not Caucasian, may provide further information for prescribing exercise to older adults in an accessible and acceptable format.

Table 5.1: Characteristics of the participants (mean ± SD)

	EX (n= 32)	EX 2 (n=27)	CTL (n=22)
Age(years)	67 ± 6.1	68 ± 5.4	68 ± 5.2
BMI (kg/m^2)	31.7 ± 7.1	30.31 ± 6.8	29 ± 9.0
Waist (cm)	97.3 ± 13.2	95.8 ± 15.5	96.7 ± 11.1
Hip (cm)	112.1 ± 13.4	108.9 ± 10.9	109.09 ± 10.8
Waist : Hip	0.87 ± 0.09	0.87 ± 0.09	0.89 ± 0.07
Hypertension (%, n, with disease)*	40 (14)	48 (13)	52 (11)
Diabetes (%, n, with disease) *	23 (8)	7 (2)	5 (1)
Osteo arthritis (%, n, with disease) *	43 (15)	33 (9)	81 (17)

* Self reported disease status.

Table 5.2: Changes in functional mobility in the EX1, EX2 and CTL groups (mean ± SD)

Variable and Assessment period	EX1	EX2	CTL	Group Effect	Time Effect	Group by time effect
Tandem Balance, right leg (s)						
Baseline	21.0 ± 10.2	28.4 ± 3.8	24.9 ± 7.5	] NS	] NS	] NS
10 weeks	26.7 ± 6.3	29.9 ± 0.4	26.0 ± 8.3			
20 weeks	28.3 ± 4.7	28.7 ± 5.0	28.4 ± 5.3			
6 min walk (m)						
Baseline	360.6 ± 84.4	352.0 ± 65.7	304.8 ± 122	] NS	] NS	] NS
10 weeks	392 ± 151.2	404.0 ± 56.8	318.1 ± 109			
20 weeks	410.5 ± 116.8	474.6 ± 102.1	373 ± 99.0			
20m walk (m/s)						
Baseline	1.15 ± 0.65	0.87 ± 0.33	1.3 ± 0.49	] NS	] NS	] NS
10 weeks	0.70 ± 0.55	0.67 ± 0.48	1.1 ± 0.65			
20 weeks	0.47 ± 0.48	0.74 ± 0.35	0.87 ± 0.6			
Grip strength – right arm (*)						
Baseline	17.23 ± 5.08	19.89 ± 5.66	18.11 ± 5.71	] NS	] NS	] NS
10 weeks	18.12 ± 4.77	21.26 ± 3.91	18.13 ± 6.52			
20 weeks	19.03 ± 4.61	21.69 ± 5.08	18.3 ± 6.03			

ANOVA for repeated measures, co-varying for % attendance at sessions.
NS – not significant
EX1 – exercise intervention group 1
EX2 – exercise intervention group 2
CTL – control group

Table 5.3: Training adaptations in blood pressure in EX1, EX2 and CTL (mean ± SD)

Variable and Assessment period	EX1	EX2	CTL	Group Effect	Time Effect	Group by time effect
Systolic BP (mmHg)						
Baseline	148 ± 13	143.14 ± 14	147 ± 13	] NS	] NS	] 0.011 ‡
10 weeks	143 ± 12	146 ± 17	147 ± 14			
20 weeks	144 ± 13	137 ± 15	150 ± 16			
Diastolic BP (mmHg)						
Baseline	90 ± 10	92 ± 10	91 ± 10	] NS	] NS	] NS
10 weeks	89 ± 10	89 ± 10	92 ± 8			
20 weeks	88 ± 9	88. ± 10	89 ± 11			

NS – not significant
EX1 – exercise intervention group 1
EX2 - exercise intervention group 2
CTL – control group
‡ Tukeys post hoc test: Significant improvement in EX2 from 10 weeks to 20 weeks, p=0.013.

Table 5.4: Training adaptations in blood pressure in EX (EX1 + EX2) and CTL (mean ± SD) for subjects who were hypertensive at baseline.

Variable and Assessment period	EX	CTL	Group Effect	Time Effect	Group by time effect
Systolic BP (mmHg)					
Baseline	146 ± 14	146 ± 14	] NS	] NS	] 0.013
10 weeks	144 ± 15	147 ± 14			
20 weeks	140 ± 14	150 ± 15			
Diastolic BP (mmHg)					
Baseline	91 ± 10	91 ± 10	] NS	] NS	] NS
10 weeks	89 ± 10	92 ± 8			
20 weeks	88 ± 10	90 ± 11			

ANOVA for repeated measures, co-varying for % attendance at sessions and baseline BMI
NS – not significant
EX1 – exercise intervention group 1
EX2 - exercise intervention group 2
EX - exercise intervention group 1 +2 (EX1 +EX2)
CTL – control group

Figure 5.1: Training adaptations to dynamic balance in EX1, EX2 and CTL (adjusted means and Standard errors)

Group by time effect: p = 0.013

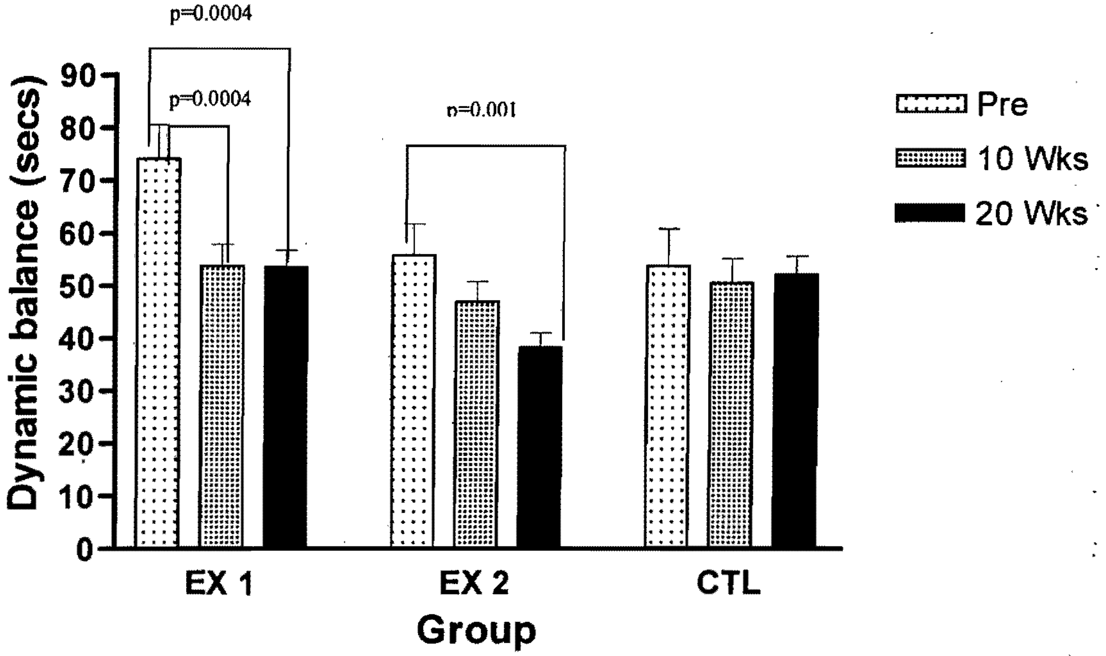

Figure 5. 2: Training adaptations to sit to stand repetitions in EX1, EX2 and CTL (adjusted means and Standard errors)

Group by time effect: p = 0.0003

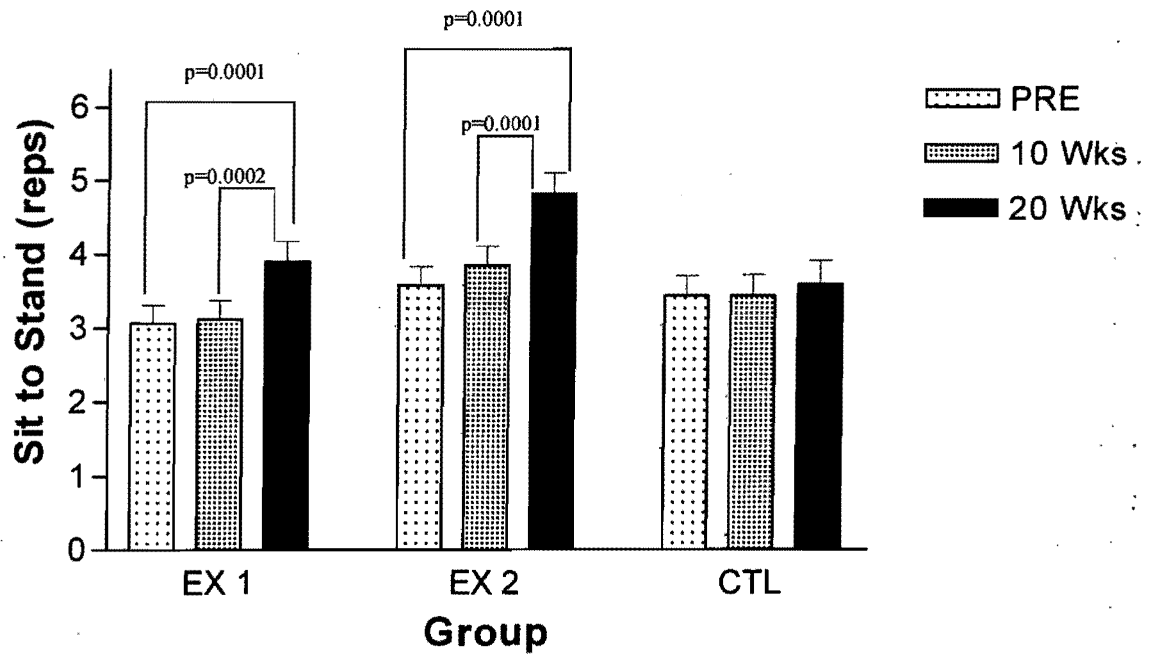

Figure 5.3: Reported weekly energy expenditure for EX1, Ex2 and CTL

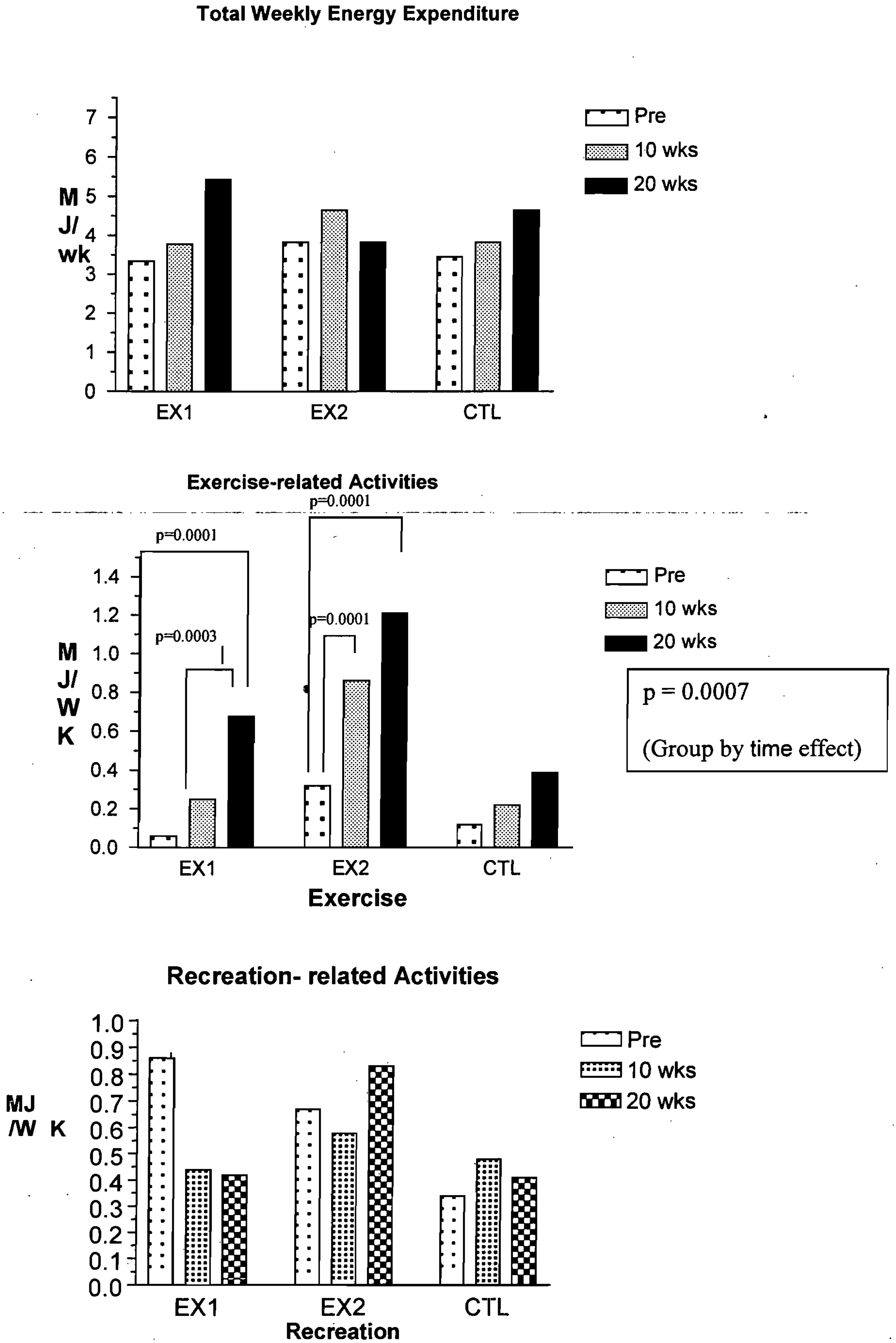

Figure 5.3. Legend:

EX1: Exercise group one
EX2: Exercise group two
CTL: control group

MJ/WK: mega joules per week. Each activity was assigned a MET value, as described by DiPietro, which was multiplied by the time spent in each activity to calculate kcal/week. The kcal/week was then divided by 1000 to calculate mega joules per week.

Figure 1a: Total weekly energy expenditure includes housework, yard ward, care giving, recreation and exercise activities.

Figure 1b. Reported exercise at 10 and 20 weeks includes the time spent in the exercise intervention sessions.

Figure 1c: Weekly recreation energy expenditure includes slow / leisurely walking, needlework, dancing (line dancing, ballroom, square, tap), lawn bowling, golf, racquet sports (tennis, racquet ball) and billiards.

CHAPTER 6:

SUMMARY AND CONCLUSIONS

6.1. Summary and conclusions

The aims of this dissertation were to interrogate the measurement of physical activity in older adults from previously disadvantaged communities, and to characterize the relationship between physical activity and both health outcomes and functional parameters.

The aim of the first study was to determine the test-re-test reliability and criterion validity of the YPAS questionnaire, which was developed for older adults, in South Africans older than 60 years and from middle to low socio economic groups. A secondary aim of this research study was to compare the YPAS to the short IPAQ questionnaires in order to determine which instrument is best suited for and most representative of measured levels of physical activity in older adults. One of the main strengths of this research study was that the sample was drawn from a population comprised largely of older women, from a working class community. These are population groups that are often under-represented in reliability and validity studies [34]. The YPAS includes activities that are common among older adults, particularly light intensity activity, which is often excluded from other physical activities assessment tools [34]. In addition, the YPAS has previously been shown to detect changes in activity after a physical activity intervention [34;42]{Harada, Chiu, et al. 2001 153 /id}. The short IPAQ provides an estimate of physical activity that can be compared globally, in both developed and developing countries [47]. We have shown that the YPAS and short IPAQ have comparable results for reliability and criterion validity in the older adults.

Because PA has previously been associated with BMD, the aim of our second study was to identify the relationship between physical activity, both historical and current, and estimated calcaneal BMD in a group of older South Africans of mixed racial ancestry who were of a low socio-economic status. Our main finding was that historical occupational related physical activity in men in early adulthood (14-21 years) was weakly but significantly correlated to estimated BMD in men. In women, the occupational related physical activity was significantly correlated with BMD, and T-score between the ages of 22 and 34 years. Furthermore, for women, current recreation PA was significantly associated with BMD, BUA and T-score. Moreover, physical activity "tracked" across all epochs, thus those who were previously physically active, were more likely to maintain their levels of activity. This study highlighted that both older men and women sampled from this community may be at increased risk for fracture and morbidity due to low estimated bone mineral density. The increased risk was evident despite the apparent "protective" effect of lifelong levels of occupational (men) and household (women) physical activity. From a public health perspective, these data highlight the importance of quantifying lifetime physical activity in all domains, including occupation.

The risk of fracture due to a fall is increased among those with low BMD. Low BMD and low levels of habitual PA have previously been associated with increased risk of frailty. The older men and women participating in the previous study had very low levels of habitual PA, particularly leisure time PA, which may place them at increased risk for future disability and frailty. Therefore, in our third study we were interested in the functional performance measures associated with increased risk of disability and frailty. Consequently, we compared objective functional performance measures with self-reported disability from the DQ98, ADL and IADL questionnaires. In addition, we summed the scores for each of the functional performance tests to create a functional ability index score, which we compared to the self-report measures.

The main finding for this study was that the DQ 98 questionnaire which was developed to assist care workers to determine the urgency with which an older adult should be admitted into institutionalized care, was unable to discriminate between community dwelling and institutionalized participants. Conversely, the FAIS, which comprised of seven functional ability tests, was able to distinguish between these two groups. We would therefore suggest that the DQ 98 be used in conjunction with the FAIS test battery in order to provide a more comprehensive evaluation of the older adult's functional status.

A secondary aim of this study was to compare two constructs of frailty, one based on a definition from Chin A Paw which combines low PA with low BMI (PA+BMI), and one based on cognitive function, to the individual functional performance measures, as well as the composite FAIS. Those classified as frail based on the PA+BMI construct, had significantly weaker performance for the FAIS test battery as well as for dynamic balance, timed up and go and gait speed. Furthermore these participants had significantly weaker performance for the ESPESE protocol described by Guralnik et al [133]. Although the cognitive score construct was also significantly different for the frail versus not frail group in the FAIS score, it was not as discriminatory for the individual functional tests as the PA+BMI construct. Our findings highlighted that frailty is multidimensional. Therefore, we suggest the use of the PA+BMI construct together with the FAIS or EPESE functional performance test battery, in addition to a measure of cognitive function when determining the risk of frailty among community dwelling and institutionalized older adults. Once the deficits in functional performance are identified, an appropriate intervention could be implemented so as to reduce the risk of disability.

Furthermore, the association between current PA and the functional performance and self-report measures in the previous study, emphasized the potential benefits of a regular PA program for older adults. Therefore the aim of our final study was to determine the effectiveness of a 20-week, low intensity, seated exercise programme conducted at community centres in producing beneficial changes in physical functioning, muscle strength and endurance, balance, habitual levels of physical activity, self perceived health status and blood pressure of older adults. The first important finding of this study was that the low intensity, community based exercise program effective in improving dynamic balance and sit to stand performance in community dwelling older adults. In addition, the significant reductions in systolic blood pressure for EX1 and EX2, as well as the sub sample who were hyptertensive at baseline, produced by the exercise intervention were similar in magnitude to studies in which anti-hypertensive medication was administered. Low intensity programs of this nature may be sustainable if volunteer workers within communities are trained to conduct the exercise sessions. In addition, the risk of injury may be reduced because participants are seated, and the low intensity reduces the likelihood that a cardiac episode will develop during the exercise session.

This dissertation provides evidence of the benefits of both current and lifetime PA in older adults from previously disadvantaged communities. In addition, YPAS and short IPAQ have been validated as tools to measure PA in this older adult population. The introduction of the FAIS test battery may play a role in identifying those at increased risk of future disability or frailty. From a public health perspective, these findings together support the measurement of PA and functional ability in older adults, and also the implementation of community based PA interventions.

CHAPTER 7:

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CHAPTER 8:

APPENDICES

8.1. Yale Physical Activity Survey (YPAS)

Interviewer: Please record appointment and time	Date:	Time:

There is very little information available on the physical activity patterns of older adults, therefore, this study is being conducted to measure how active older adults are. In addition, we would like to determine which activities older adults participate in most frequently.
I am going to ask you a few questions about the activities that you usually perform, as part of your daily routine and also for leisure. There are no right or wrong answers. Your name will not be used in the results, therefore the information that you give me will be confidential and only used for research purposes.
BY giving up some of your time to fill in the questionnaires, you will enable us to understand the health problems that some of the elderly people may face. This information may help us to plan ways to improve the health and well being of the elderly.

Code: ____________________

Name: ____________________

Address 1: ____________________

Address 2: ____________________

Telephone number: ____________________

Date of birth: ____________________

Age: ____________________

Date of interview: ____________________

Part 1

Interviewer: (please read to participant): We are interested to learn about the types of activities which are part of your regular routine. I am going to show you lists of common types of physical activities. Please tell me how much time (in minutes or hours) you spent during the past week.

Interviewer: Show the participant Card number 1.

Activity	**Time**		**Intensity code**
	Hours	**Minutes**	
Work			
Shopping (e.g., grocery, clothes)	______	______	3.5
Stair climbing while carrying a load.	______	______	8.5
Laundry:	______	______	
Unloading/ loading machine, hanging, folding only	______	______	3.0
Washing clothes by hand	______	______	4.0
Light housework: tidying, dusting, sweeping, collecting rubbish in the home, polishing, ironing.	______	______	3.0
Heavy housework: vacuuming, mopping, scrubbing floors and walls, moving furniture, boxes or rubbish bins.	______	______	4.5
Food preparation: chopping, stirring, moving about to get food items and pans.	______	______	2.5
Food service: setting table, carrying food, serving food			2.5
Dish washing: clearing the table, washing / drying dishes, putting dishes away.	______	______	2.5
Light home repair. Small appliance repair, light home maintenance / repair.	______	______	3.0
Heavy home repair: painting, carpentry, washing/polishing car.	______	______	5.5
Other: ______________	______	______	____

Yard work	Hours	Minutes	
Gardening, pruning, planting, weeding, digging, hoeing	______	______	4.5
Lawn mowing (walking only)	______	______	4.5
Clearing walks/driveways: sweeping, shoveling, raking	______	______	5.0
Other: ______________	______	______	______

Care taking	Hours	Minutes	
Older or disabled person (lifting, pushing wheelchair)	______	______	5.5
Child care (lifting, carrying, pushing pram)	______	______	4.0

Exercise	Hours	Minutes	
Brisk walking	______	______	6.0
Pool exercises, stretching, yoga	______	______	3.0
Vigorous calisthenics, aerobics	______	______	6.0
Cycling	______	______	6.0
Swimming (laps only)	______	______	6.0
Other	______	______	______

Recreation	Hours	Minutes	
Leisurely / slow walking	______	______	3.5
Needlework: knitting, sewing, needlepoint, etc	______	______	1.5
Dancing: line, ballroom, tap, square etc	______	______	5.5
Bowling	______	______	3.0
Golf	______	______	5.0
Racquet sports: tennis, squash	______	______	7.0
Billiards	______	______	2.5
Other	______	______	______

8.2. SHORT INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (IPAQ)

Short Usual week – version 8.

(Note: Examples of activities may be replaced by culturally relevant examples with the same MET values; see Ainsworth et al.)

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. This is part of a large study being conducted in many countries around the world. Your answers will help us to understand how active we are compared with people in other countries.

I am going to ask you about the time you spend being physically active in a usual week. Please answer each question even if you do not consider yourself to be an active person. I will be asking you about activities you do at work, to get from place to place, as part of your house and yard work, and in your spare time for recreation, exercise or sport.

1a.
Now think about all the vigorous activities which take hard physical effort that you might do *during a usual week*. Vigorous activities make you breathe much harder than normal and may include heavy lifting, digging, aerobics, or fast bicycling. Think about *only* those physical activities that you do for at least 10 minutes at a time.

On how many days in a usual week do you do vigorous physical activities?
[Interviewer clarification: Think only about those physical activities that you do for at least 10 minutes at a time.]

[Interviewer: Include all jobs]

_______ days per week
Refused [Interviewer: do not read]
Don't know [Interviewer: do not read]
[Interviewer: If respondent answers zero, refuses or does not know, skip to question 2a.]

1b.
How much time in total would you usually spend on one of those days doing **vigorous** physical activities?

_______ Hours _______ Minutes

[Interviewer clarification: Think only about those physical activities that you do for at least 10 minutes at a time.]
[Interviewer probe: An average time per day is being sought. If the respondent cant answer because the pattern of time spent varies widely from day to day, ask: "How much time in total would you spend during a **usual week** doing vigorous physical activities?"

_______hours _______minutes per week]

2a.
Now think about all the activities which take **moderate physical** effort that you might do *during a usual week*. Moderate physical activities make you breathe somewhat harder than normal and may include carrying light loads, bicycling at a regular pace, or doubles tennis. Do not include walking. Again, think about *only* those physical activities that you do for at least 10 minutes at a time.

On how many days in a usual week do you do **moderate** physical activities?
[Interviewer clarification: Think only about those physical activities that you do for at least 10 minutes at a time.]

[Interviewer: Include all jobs]

______ days per week
Refused [Interviewer: do not read]
Don't know [Interviewer: do not read]
[Interviewer: If respondent answers zero, refuses or does not know, skip to question 3a.]

2b.
How much time in total would you usually spend on one of those days doing **moderate** physical activities?

______ Hours ______ Minutes
[Interviewer clarification: Think only about those physical activities that you do for at least 10 minutes at a time.]
[Interviewer probe: An average time per day is being sought. If the respondent cant answer because the pattern of time spent varies widely from day to day, ask: "How much time in total would you spend during a **usual week** doing moderate physical activities?"

______hours ______minutes per week]

3a.
Now think about the time you spend walking during a usual week. This includes walking at work and at home, walking to travel from place to place, and any other walking you might do solely for recreation, sport, exercise or leisure.

On how many days in a usual week do you do walk for at least 10 minutes at a time?
[Interviewer clarification: Think only about the walking that you do for at least 10 minutes at a time.]

[Interviewer: Include all jobs]

______ days per week
Refused [Interviewer: do not read]
Don't know [Interviewer: do not read]
[Interviewer: If respondent answers zero, refuses or does not know, skip to question 4a.]

3b.
How much time in total would you usually spend walking on one of those days?

______ Hours ______ Minutes
[Interviewer probe: An average time per day is being sought. If the respondent cant answer because the pattern of time spent varies widely from

day to day, ask: "How much time in total would you spend during a **usual week** doing moderate physical activities?"
_______hours _______minutes per week]

3c. At what pace do you **usually** walk?
_______A vigorous pace, that makes you breathe much harder than normal.
_______A moderate pace that makes you breathe somewhat hared than normal.
_______A slower pace where there is no change in your breathing.

[Interviewer probe: A usual pace is being sought. If the respondent can't answer because the pace varies from day to day, or from across job, transportation and leisure categories, ask: 'How much time would you spend in a usual week walking at a slow pace?
_______hours _______minutes per week]

The last questions are about the time you spend sitting each day while at work, at home, whole doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television.

4a.
How much time in total do you usually spend sitting on a **week day**?

_______ Hours _______ Minutes

[Interviewer clarification: Include time spent lying down (awake) as well as sitting]

[Interviewer probe: An average time per day is being sought. If the respondent cant answer because the pattern of time spent varies widely from day to day, ask: "How much time **in total** would you spend sitting during a **usual week**?"
_______hours _______minutes per week]

4b.
How much time in total do you usually spend sitting on a **weekend day**?

_______ Hours _______ Minutes

8.3. LIFETIME PHYSICAL ACTIVITY QUESTIONNAIRE

LTPA: Household **Subject Code: _______**

14-21 years

Household Activity Examples	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

22-34 years

Household Activity Examples	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

35-49 years

Household Activity Examples	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

50-64 years

Household Activity Examples	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

≥ 65 years

Household Activity Examples	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

1 = minimal effort such as standing or slow walking;
2 = not exhausting but some increase in heart rate or sweating;
3 = increase heart rate and heavy sweating, lifting heavy objects etc.

LTPA: Occupation

Subject Code: _______

14-21 years

Occupation	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

22-34 years

Occupation	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

35-49 years

Occupation	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

50-64 years

Occupation	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

≥ 65 years

Occupation	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

1 = minimal effort such as standing or slow walking;
2 = not exhausting but some increase in heart rate or sweating;
3 = increase heart rate and heavy sweating, lifting heavy objects etc.

LTPA: Leisure

Subject Code: _______

14-21 years

Leisure Time Activity	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

22-34 years

Leisure Time Activity	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

35-49 years

Leisure Time Activity	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

50-64 years

Leisure Time Activity	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

≥ 65 years

Leisure Time Activity	Intensity Rating	Years	Months/ Yr	Days/ wk	Time/day Hrs	Min

1 = minimal effort such as standing or slow walking;
2 = not exhausting but some increase in heart rate or sweating;
3 = increase heart rate and heavy sweating, lifting heavy objects etc.

8.3.2. Interviewer's Script

You will be referred to as" I / interviewer" and the person you are interviewing will be refereed to as the "you / the subject".

- You will ask three sets of questions per life phase – namely occupational, household and leisure.
- The life phases are 14-21 years, 22 to 34 years, 35 to 49 years, 50 –64 years and older than 65 years.
- Start each life phase by saying; lets think back to when you were between the ages of... (Either 14-21; or 22-34; or 35 – 49; or 50-65; or since your 65th birthday).

Part One: Occupational Activity

Interviewer: "Lets think back to when you were between the ages of 14 and 21 *years (insert appropriate stage of life)*."

1. *Did you work? (If the subject answered no, write in did not work).*

2. *If yes, ask; "What kind of work did you do?*

Interviewer: We are interested in the kind of work they did, not where they worked. If they changed their occupational activity, from a seamstress to a fish cleaner for example, then write seamstress as activity one, and fish cleaner as activity two. If the subject has changed their occupational activity more than three times in the selected life phase, then write the activities that the subject held the longest.

3. *How would you rate this activity? Interviewer show and explain the 4 rating levels –*

Card One

1. Job required sitting with minimal walking;
2. Jobs requiring minimal activity such as standing or slow walking, no increase in heart rate or sweating;
3. jobs requiring carrying of light loads (2-3kg), continuos walking, increased heart rate or sweating;
4. Jobs requiring lifting heavy loads, brisk walking, heavy sweating, increased heart rate.

4. Did you work every day? / How many days per week did you spend at work?

5. How many hours per day did you work? Give an average.

6. How many months of the year did you work?

7. Did you work every year from the age of ..... (*Interviewer: insert applicable life phase here*)?

Part Two: Household Activities

Interviewer: "Lets go back to when you were between ____. years and ___ years".

1. *Did have to help with the cleaning / running of your home?*

2. Look at these three categories of activities. Which activity did you spend most of your time doing? Give one activity per category. (*Interviewer, show the subject card four)*

Household activities - categories

Minimal effort	**Not exhausting but some increase in heart rate**	**Heavy sweating, lifting heavy objects, increased heart rate**
Washing dishes *Ironing* Dusting Cooking food Food service	Packing cupboards Washing windows Mopping Sweeping Washing clothes by hand Hanging up clothes	Cleaning garage Child care Collecting rubbish / dirt Moving furniture Home repairs Gardening Shopping Scrubbing floors – by hand

3. *How much time would spend on this activity?*

4. Would you do this every day? / How many days per week would you do this activity?

5. How many months of the year would you have to do this activity?

6. Did you do this activity every year from ... years to .... years (*interviewer, insert applicable life phase here*)?

Part Three: Leisure Activities

Interviewer: "This is the last section of the interview. Lets think back to when you were between the ages of ...and ... again."

1. *When you were not at work or helping around the house, what kind of activities or sport did you do?*

2. How would you rate this activity? *(Interviewer ask and show the subject card three).*

1 = requires sitting with minimal walking
2 = minimal activity such as standing or slow walking, no increase in heart rate or sweating;

3= activities that are not exhausting, but increase heart rate and sweating slightly, such as brisk walking;
4 = activities causing heavy sweating, increased heart rate.

3. *How many days per week were you able to perform this activity?*

4. *How many months per year would you do this activity?*

5. *Did you continue doing / participating in this activity every year from .... to ... years?*

6. *When you did this activity, how much time would you spend on it each occasion?*

8.4. General Information Questionnaire

A GENERAL AND DEMOGRAPHIC INFORMATION

Firstly, we would like to ask some questions about you. Everything you say will be strictly confide

Office use

1. Interviewer's name: ....

2. Date of interview:

D	D	M	M	Y	Y	Y	Y
				2	0		

3. Name of Old age home / Community Center:..

4. Participant's Code: ....

5. Participant's Name: ....

6. Is the participant...

Community dwelling, independent	1
Community dwelling with family / friend assistance	2
Living at a center but independent	3
Living at a center, and with assistance	4

7. Gender:

1 Male	2 Female

8. How old are you at present? ....

8.1 Date of birth:

D	D	M	M	Y	Y	Y	Y
				1	9		

9. What is your marital status?

Never married	1
Married	2
Single	3
Divorced / separated	4
Widow / widower	5
Living with partner	6

10. Where did you spend most of your childhood years? (Up to ten years)

A farm	1
A small town	2
A large town / city	3
A country outside SA	4
Cannot say	5

11. What is the highest standard that you have passed at school?

No formal education – cannot read /write	1
No schooling - can read /write	2
Standard 3 or lower	3
Standard 4-5	4
Standard 6-7	5
Standard 8-9, or equivalent	6
Standard 8-9, or equivalent with diploma	7
Standard 10, matriculation or equivalent	8
Standard 10 and diploma	9
Standard 10 and degree	10
Standard 10 and more than one post school qualification	11

12. What was your occupation most of your life?...

13. Are you presently employed?

No	1
Yes – full time	2
Yes – part time	3

14. Do you receive any of the following grants?

	Yes	No
Old age pension	1	2
Disability grant	1	2
Other: Please specify:	1	2

15. How many people in your household receives one of the following sources of income? (excluding yourself)

Old age pension	
Disability grant	
Wages/salary	
Other: Please specify:	

16. What type of dwelling do you live in?

House (single unit)	1
Semi-detached house (2 units joined together)	2
Row house (more than 2 units attached to each other)	3
Room / flat on same premises as house	4
Flat / apartment	5
Room in boarding house	6
Single room in house / flat / building	7
Shack	8
Other, please specify	9

17. How many people, including children live in this household?
....

18. How many rooms are used for sleeping? (Excluding bathroom and kitchen?
....

19. What is your religion?

Protestant	1
Catholic	2
Muslim	3
Christian	4
No religion	5
Other, please specify	6

B. PERSONAL MEDICAL HISTORY – Now tell us about yourself and your health

1. How would you rate your health at present/

Very good	5
Good	4
Average	3
Poor	2
Very Poor	1

2. Would you say that your health is better, about the same, or not as good as that of most people your age?

Better	3
About the same	2
Not as good	1

3. How often do you worry about your health?

Don't worry at all	3
Occasionally	2
Worry a great deal	1

4. Which of the following aids do you use, and if not, do you need this aid?

	Yes	No – do not need this aid	No – but need to obtain this aid	Refuses to say
Dentures	1	2	3	4
Spectacles / contact lenses	1	2	3	4
Cane / crutch / walking frame	1	2	3	4
Wheelchair	1	2	3	4
Hearing aid	1	2	3	4

5. Has your doctor or a nurse ever told you that you **have or had** any of the following?

	Yes	No	Don't Know
Hypertension / high blood pressure	1	2	3
Heart attack or angina	1	2	3
Any other heart condition	1	2	3
Stroke	1	2	3
High blood cholesterol (high blood fats)	1	2	3
Diabetes or sugar	1	2	3
Asthma	1	2	3
Peripheral vascular disease (poor blood flow in limbs)	1	2	3

6. Do you use medication for any of the following conditions?

	Yes	No	Don't Know
Hypertension / High blood pressure	1	2	3
Diabetes or sugar	1	2	3
High blood cholesterol	1	2	3
Angina or chest pain	1	2	3
Any other heart condition	1	2	3
Stroke	1	2	3
Asthma	1	2	3
Menopause (hormones)	1	2	3

3. Can you name the medications that you use? (*Interviewer – ask respondent to show you the medication*)

1) ....
2) ....
3) ....
4) ....
5) ....
6) ....
7) ....
8) ....

C_1 HABITS AND LIFESTYLE – Smoking

1. Have you ever smoked tobacco, used snuff or chewed tobacco? | 1 Yes | 2 No |

If no Go to Part C_2

2. Have you ever smoked on a daily basis? | 1 Yes | 2 No |

If no Go to Q7

3. How old were you when you started smoking on a daily basis? ....

4. On average, what number of the following items do you or did you use on a daily basis?

No. of manufactured cigarettes	
No. of hand-rolled cigarettes	
No. of pipefulls of tobacco	
No. of cigars/cheroots/cigar rolls	
No. of times you use snuff / day	
No. of times you chew tobacco / 'pruimpie' / day	

5. Do you still smoke on a daily basis? | 1 Yes | 2 No |

6. How many years ago did you stop smoking on a daily basis? ....

7. Do you now smoke | 1 Occasionally | 2 Not at all |

C_2 Habits and lifestyle – Alcohol

1. Have you ever drunk alcohol? | 1 Yes | 2 No |

If no, Go to Part C_3

2. Do you drink alcohol now? | 1 Yes | 2 No |

If yes, Go to Q3

2.1 How many years ago did you stop drinking alcohol? ....

If stopped > 1 year ago, go to Part C_3

If stopped < 1 year ago, answer Q3 & Q4, then go to Part C_3

USE THE FOLLOWING AS A GUIDE TO THE QUESTIONS THAT FOLLOW

ONE DRINK *= 1 TOT*

= 25 ml HARD LIQUOR (rum, gin, whiskey, etc)

= 60 ml SWEET WINE/SHERRY

= 120 ml TABLE WINE

= 340 ml BEER ('dumpie')

= 1L SORGHUM BEER

= 'concoction'

3. How much alcohol do you/did you drink on average, during the week (Monday-Thursday)?

None	1
1-2 drinks per day	2
3-4 drinks per day	3
> 5 drinks per day	4
Communal drinking	5

4. How much alcohol do you/did you drink on average, over the weekend (Friday-Sunday)?

None	1
1-2 drinks per day	2
3-4 drinks per day	3
> 5 drinks per day	4
Communal drinking	5

5. Have you ever felt that you should cut down on your drinking? | 1 Yes | 2 No |

6. Have people annoyed you by criticizing your drinking? | 1 Yes | 2 No |

7. Have you ever felt bad or guilty about your drinking? | 1 Yes | 2 No |

8. Have you ever had a drink first thing in the morning to steady your nerves or get rid of a hangover? | 1 Yes | 2 No |

9. Has your doctor or other clinic staff ever advised you to cut down on your drinking? | 1 Yes | 2 No |

C3 . HABITS AND LIFESTYLE – Exercise

Lastly, we would like to ask about your physical activity

1. Which of the following activities have you done during the past week?

		Yes	No	Cannot remember
1.1	Watched television	1	2	3
1.2	Read the newspaper or magazine	1	2	3
1.3	Listened to the radio	1	2	3
1.4	Practiced a hobby, or did handiwork/handcraft (sewing, woodwork, etc)	1	2	3
1.5	Received visits / went visiting	1	2	3
1.6	Went to church / place of worship	1	2	3

2. Activities of daily living and instrumental activities of daily living
Which of the following activities are you able to perform? Do you need help with these activities/

		Independently, without help	Able to, but need help	Unable to perform activity	Never does it but able to
2.1	Preparing food	1	2	3	4
2.2	Shopping	1	2	3	4
2.3	Travel to places further than walking distance	1	2	3	4
2.4	Housework	1	2	3	4
2.5	Washing clothes	1	2	3	4
2.6	Use telephone	1	2	3	4
2.7	Work with money	1	2	3	4
2.8	Moving form the bed to a chair	1	2	3	4

		Independently, without help	Able to, but need help	Unable to perform activity	Never does it but able to
2.9	Take medication on their own	1	2	3	4
2.10	Walking 200-300 m	1	2	3	4
2.11	Eating	1	2	3	4
2.12	Dressing	1	2	3	4
2.13	Bathing	1	2	3	4
2.14	Going to the toilet	1	2	3	4

8.5. 6-ITEM COGNITIVE SCORE TEST

Participant Code: ____________________ Date: __________

Time of test: ____________________

	Answers	Maximum Error	Score	Weight	Weighted Score
Ngowuphi lo nyaka (*What year is it now*)		1		*4	
Yeyiphi le nyanga (*What month is it now?*)		1		*3	
Linganisa uphinde la mazwi ndiwathethayo. Yi address le (*Memory phrase (Address) - repeat after me*) **Pumla / Zibi / Z69 / Jama Road / Khayelitsha**					
Ngubani ixesha ngoku (*About what time is it now?) (within 1 hour*)		1		*3	
Bala ukusuka ku 20-1 (*Count backwards 20-1*)		2		*2	
Biza inyanga uqala emva (*Say months in reverse order*)		2		*2	
Yitsho laa mazwi akwisicatshulwa esingentla (idelisi) (*Repeat the memory phrase*)		5		*2	

Total

Score 1 for each incorrect response.

- Write down answers to:

  ....

  ....

- Count backwards:

  ....

  ....

- Months in reverse order:

  ....

  ....

- Memory phrase:

  ....

  ....