Physical activity, body composition and handgrip strength among South African adults: the PURE study

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DECLARATION

Prof. MA Monyeki (supervisor), Prof. SJ Moss (co-supervisor), and Prof. C Pienaar (assistant co-supervisor), and the co-authors of the two articles in this dissertation, hereby give permission to the candidate, Sindisiwe Shozi, to include these articles as part of her Master’s dissertation.

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DEDICATION

This dissertation is dedicated to my late mother Mrs Agnes Jabulile Shozi.

ABSTRACT

There is a consistent and progressive trend concerning a decrease in handgrip strength and physical activity with increased age that have significant implications for public health. It has been revealed that poor muscle strength is associated with lower levels of physical activity that can increase the likelihood of falls resulting in injuries. Handgrip strength is a marker of muscle quality. Regular participation in physical activity is, therefore, a useful intervention to improve handgrip strength and lower other health risk factors associated with increased age in an attempt to prolong the life. However, there are limited studies in South Africa (especially in the North West) that investigated physical activity, body composition and handgrip strength among young and middle adults. Two manuscripts were prepared from this study. In 2015, a cross-study of 910 participants (men=198; women=490) between the ages of 35-70 years formed part of a multidisciplinary Prospective Urban and Rural Epidemiological (PURE) in the North West of South Africa. Physical activity information was gathered by the use of a self-reported international physical activity questionnaire-short form. Handgrip strength was measured by a hand-held model (T.K.K.54010 Takei) dynamometer; while anthropometric indicators of height, body mass, and waist circumference were measured using the standard procedures described by the International Society for the Advancement of Kinanthropometry.

The first article focuses on physical activity and handgrip strength in relation to body mass index among adults in the North West. The result showed that 29% and 22% of the men and women were underweight, respectively; while 22% of the women were overweight and 26% of the men were reported as obese ($p<0.001$). The men were more physically active, taller and underweight compared to the women in all age groups. The women reported high mean values for triceps, subscapular and waist circumference compared to the men. Regardless of age and gender, the underweight and normal weight groups reported higher physical activity levels and handgrip strength compared to the overweight and obese groups. The handgrip strength according to age groups was significantly ($p<0.05$) better men compared to women ($p<0.05$) 42-49 age group: men 34.81 ± 11.13 kg versus women 26.29 ± 7.72 kg; 50-59 age group: men 34.05 ± 9.19 kg versus women 25.12 ± 6.67 kg; 60-70 age group: men 30.28 ± 8.69 kg versus women 23.27 ± 6.44 kg. The overweight and obese men performed poor during the minute spent in moderate-vigorous physical activity per week.

The second article focuses on the relationship between physical activity, body composition, and handgrip strength among adults in the North West. About 60% of the participants reported sufficient physical activity per week. Seventeen percent (17%) of the men and 27% of the women were physically inactive per week. The handgrip strength performance significantly ($p<0.05$) differed according to age. In general, the handgrip strength of the participants in the study was poor when compared to the available handgrip strength norms. The participants younger than 50 years outperformed the older groups with men being stronger than the women are. The men and women who were sufficiently active per week significantly ($p<0.05$) performed better than the other groups. A positive correlation was found between handgrip strength and body mass index. A negative correlation was found between moderate to vigorous physical activity ($r= -0.12$; $p=0.001$) and age. Handgrip strength in both the men ($r= -0.23$; $p= 0.001$) and women ($r= -0.18$; $p<0.001$) correlated negatively with age. Given the health implications of the current findings, strategic interventions aiming at the reduction of obesity and physical inactivity are needed. As such, the study recommends an urgent strategic physical intervention in older men and women to improve their quality of life.

Keywords: body composition, body mass index, handgrip strength, obesity, overweight, physical activity, physical inactivity

OPSOMMING

Daar is ’n konsekwente en progressiewe tendens met betrekking tot ’n afname in handgreepsterkte en fisieke aktiwiteit met veroudering wat beduidende implikasies vir publieke gesondheid inhou. Dit het aan die lig gekom dat swak spierkrag geassosieer word met laer vlakke van fisieke aktiwiteit wat die waarskynlikheid van beserings tydens ’n val verhoog. Handgreepsterkte word in navorsing as ’n merker van spierkwaliteit aangedui. Gereelde deelname in fisieke aktiwiteit is dus ’n waardevolle hulpmiddel om handgreepsterkte te verbeter en om gesondheidsrisiko’s wat geassosieer word met ouderdom te verminder om sodoende die lewensduur van volwassenes te verleng. Daar is egter beperkte studies in Suid-Afrika beskikbaar (veral in die Noordwes) wat die fisieke aktiwiteit, liggaamsamestelling en handgreepsterkte van jong en middeljarige volwassenes ondersoek. Twee manuskripte is vir hierdie studie voorberei. In 2015, het ’n totaal van 910 deelnemers (mans=198; vroue=490) tussen die ouderdom van 35-70 jaar aan ’n kruis-A studie wat deelgeneem wat deel gevorm het van die multidissiplinêre *Prospective Urban and Rural Epidemiological (PURE)* kruisdeursnee studie wat in die Noordwes, Suid-Afrika, plaasgevind het. Die analises vir die studie het slegs plaasgevind met deelnemers met ’n volledige datastel oor die veranderlikes van belang. Inligting oor fisieke aktiwiteit is versamel deur middel van die gebruik van ’n *self-report international physical activity questionnaire-short form*. Handgreepsterkte is gemeet deur gebruik te maak van ’n handmodel (T.K.K.54010 Takei) dinamometer. Antropometriese aanwysers van lengte, liggaamsmassa en middellyfomtrek is gemeet deur van metings gebruik te maak wat deur die *International Society for the Advancement of Kinanthropometry* voorgeskryf word.

Die eerste artikel fokus op fisieke aktiwiteit en handgreepsterkte in verhouding tot die liggaamsmassa-indeks van volwassenes in die Noordwes. Die bevindings dui aan dat 29% van die mans en 22% van die vroue ondergewig was terwyl 22% van die vroue oorgewig en 26% van die mans vetsugtig was ($p<0.001$). Die mans was meer aktief, langer en ondergewig as die vroue in al die ouderdomsgroepe. Vir die vroue is daar hoër gemiddeldes gerapporteer vir triceps, subscapular en middellyfomtrek in vergelyking met die mans. Ongeag ouderdom en geslag, het die ondergewig- en normale gewig-groepe hoër vlakke van fisieke aktiwiteit en handgreepsterkte getoon in vergelyking met die oorgewig en vetsugtige groepe. Die handgreepsterkte van die mans volgens die ouderdomsgroepe was beduidend beter ($p<0.05$) in vergelyking met die vroue ($p<0.05$); 42-49 ouderdomsgroep: mans 34.81 ± 11.13 kg teenoor vroue 26.29 ± 7.72 kg; 50-59 ouderdomsgroep: mans 34.05 ± 9.19 kg teenoor vroue 25.12 ± 6.67 kg; 60-70 ouderdomsgroep: mans 30.28 ± 8.69 kg teenoor vroue 23.27 ± 6.44 kg. Die oorgewig en vetsugtige mans het swak gevaar tydens een minuut se matige tot vinnige fisieke aktiwiteit per week.

Die tweede artikel fokus op die verhouding tussen fisieke aktiwiteit, liggaamsmassa, en handgreepsterkte van volwassenes in die Noordwes. Ongeveer 60% van die deelnemers het voldoende fisieke aktiwiteit per week gerapporteer. Sewentien persent (17%) van die mans en 27% van die vroue was onaktief. Handgreepsterkte het beduidend ($p<0.05$) verskil ten opsigte van ouderdom. In die algemeen was die handgreepsterkte van die deelnemers swak in vergelyking met die beskikbare norme vir handgreepsterkte. Die deelnemers jonger as 50 jaar het beter gevaar as die ouer groepe en die mans was sterker as die vroue. Die mans en vroue wat voldoende aktief was per week het beduidend beter gevaar ($p<0.05$) as die ander groepe. Daar was 'n positiewe korrelasie tussen handgreepsterkte en liggaamsmassa-indeks. 'n Negatiewe korrelasie het bestaan tussen matige en vinnige fisieke aktiwiteit ($r= -0.12$; $p=0.001$) en ouderdom. Daar was 'n negatiewe korrelasie tussen die handgreepsterkte van beide die mans ($r= -0.23$; $p= 0.001$) en vroue ($r= -0.18$; $p<0.001$) en ouderdom. Gegewe die gesondheidsimplikasies van die huidige bevindings, is strategiese intervensie van kardinale belang om vetsugtigheid en onaktiwiteit aan te spreek. Hierdie studie beveel dus 'n dringende strategiese fisieke-intervensie aan wat moet fokus op ouer mans en dames om hulle lewenskwaliteit te verbeter.

Sleutelterme: liggaamsmassa-indeks, liggaamsamestelling, handgreepsterkte, vetsugtigheid, oorgewig, fisieke aktiwiteit, fisieke onaktiwiteit

ABBREVIATIONS AND ACRONYMS

B:

BC	Body composition
BMI	Body mass index

C:

cm	Centimetres

H:

HGS	Handgrip strength

K:

Kg	Kilogrammes
Kg/m2	Kilogrammes per metre squared

L:

LTPA	Levels of leisure time physical activity

M:

MET	Metabolic equivalents
MVPA	Moderate to vigorous physical activity per week.

N:

N	Mean value
NCDs	Non-communicable diseases

P:

P	Significance level

PA	Physical activity
PURE	Prospective Urban Rural Epidemiology
R:	
r	Correlation coefficient
S:	
SA	South Africa
SD	Standard deviation
W:	
WC	Waist circumference
WHO	World Health Organization
WtHR	Hip-to-waist ratio

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CHAPTER 1
INTRODUCTION

1.1 Introduction

Poor muscle strength among the elderly has a significant impact on public health (Den Ouden *et al.,* 2011:208), as it has the potential to limit physical activities in their daily lives (Den Ouden *et al.,* 2011:208; Vermeulen *et al.,* 2011). Poor muscle strength also increases the likelihood of falls that can result in injuries (Cooper *et al.,* 2010; Sayer *et al.,* 2006:663). Regular physical activity has a positive relation with general muscle strength (Rantanen *et al.,* 1997:1439; Sternäng *et al.,* 2015:270); and handgrip strength is one of the most common indicators of measuring muscle strength (Roberts *et al.,* 2011:423). Handgrip strength decreases due to age-related physiological changes and changes in biological functioning (Bohannon, 2008a:3). In a comparative study focusing on body composition, handgrip strength, functional capacity and physical activity among elderly Koreans and Korean immigrants, Sin *et al*. (2009:25) reported that older men measured stronger handgrip strength values than their female counterparts. Furthermore, females who are more physically active when they are older, exhibit better handgrip strength than male counterparts who are less physically active (Sternäng *et al*., 2015:44). According to other studies (Kohl *et al.,* 2012; Wagner & Brath; 2012: S39), non-communicable diseases (NCD) account for more than 63% of death globally. In South Africa, black women have the highest level of physical inactivity and obesity, placing at a greater risk in developing chronic diseases when compared to men (Van der Merwe & Pepper, 2006:318-319).

1.2 Problem statement

Maintaining a healthy body weight/body mass throughout life would prevent a decline in muscular strength (Yancey *et al.,* 2004). Physical activity also plays a very important role in maintaining muscular strength and cardiovascular health by reducing the risk of conditions characterised by being either overweight or obese (Blair & Brodney, 1999; Gill & Malkova, 2006:409). Moreover, overweight or obesity would contribute to the deterioration of joints (Blair & Brodney, 1999). Becoming overweight or obese in early life can result in a reduced level of physical activity, to contribute significantly to a decrease in muscle strength (Stenholm *et al.,* 2011:345). Fogelholm (2010:202) found that a high body mass index (BMI) and physical inactivity are associated with an increased risk of ailments, such as Type 2 diabetes and cardiovascular disease (Cooper *et al.,* 2011:20; Artero *et al.,* 2012:357).

Regular physical activity is associated with improved physical fitness and physical function, and plays an important role in the prevention of NCD due to lifestyle (Xiaoxing & Baker, 2004:1572). Physical activity and the absence of diseases are influential factors in maintaining both muscle mass and muscle strength, and crucial in maintaining functional independency and daily activity among adults (Guo & Chumlea, 1999). Furthermore, encouraging physical activity and developing effective exercise programmes to strengthen muscles among older adults are some of the strategies for maintaining and improving physical health. These programmes are beneficial to people whose health is at risk by the effect of ageing (Sin *et al.,* 2009:2).

Some other physical health strategies include increasing the time spent on low-intensity physical activities, because low-intensity physical activities are associated with a lower BMI and stronger handgrip strength values (Bann *et al*., 2015). Individuals who are inactive and who have a high percentage of body fat, a high BMI and a large waist circumference are at a greater risk of developing walking limitations in comparison with those who are physically active and have normal body compositions (Yancey *et al.*, 2004:151; Stenholm *et al*., 2008:462). Consequently, programmes aiming to promote health should target people of all ages, as the risk of suffering from chronic diseases starts in childhood and increases with age (Warburton *et al.,* 2006:807).

Deurenberg *et al.* (1998:45), Gallagher *et al.* (1996:235), and Ranasinghe *et al.* (2013:801), has provided evidence of a positive relationship between BMI and body fat percentage across gender and age groups. BMI can be an important means of determining the body fat percentage of individuals and it can be significant indicator of body composition (Meeuwsen *et al.,* 2010:565; Ranasinghe *et al.,* 2013:804). Body mass index, body weight and body height are relatively easy to measure. The skinfold callipers technique is widely used to estimate subcutaneous fatness at various anatomic sites and provides a more acceptable estimate of health risk factors associated with NCD (Revick & Isreael, 1986:994). According to Janssen *et al*. (2002:2099), high waist circumference (WC) independently predicts NCD related to obesity. In addition to BMI and a skinfold measures, WC is also used to predict obesity-related diseases.

Non-communication diseases related to obesity are found to be extremely high among women in Sub-Saharan Africa (e.g., South Africa, Botswana, Namibia and Zimbabwe) (Walker *et al.,* 2001:368). In a survey conducted by Kruger *et al.* (1999:160) focusing on transitional African communities in the North West (South Africa), it was found that inactivity and an independency on the degree of urbanisation are associated with high obesity levels (p= 0.0007). A better understanding of the medical hazards of obesity should act as a motivator to prevent excessive weight gain (Kruger *et al.,* 2001:739). Muscle strength is found to be one of the most dominant factors to reduce the probabilities of physical and functional limitations in the elderly who are obese (Leong *et al.,* 2016; Germain *et al.,* 2016:4).

Muscle strength appears to be a critical component in maintaining physical function, mobility and vitality in older adults. It is, therefore, important to identify factors that contribute to the loss of muscular strength in elderly persons (Goodpaster *et al.,* 2006:1059). Age and gender significantly influence handgrip strength (Budziareck *et al.,* 2008:357). Age and gender differences in handgrip strength with men exhibiting greater handgrip strength in comparison to females in each age category (Kallman *et al.,* 1990; Syddall *et al*., 2003:652-653; Kerr, 2006; Ramlagan *et al*., 2014:6). Nevertheless, the expected handgrip strength measurement of individuals from any given age group or gender group varies according to their geographic regions and/or ethnicity (Leong *et al*., 2016:9).

A handgrip strength measurement is a visible, easy-to-use, portable, affordable and the most frequently used tool in clinical settings to indicate overall health (Boissey *et al.,* 1999; Massey-Westrop *et al.,* 2004; Bohannon, 2008b:9). Handgrip strength increases with age from early childhood through puberty and begins to decline by the age of 45 years (Smith *et al.,* 1999:1459). Therefore, a low handgrip strength maybe an early non-cognitive marker of physical decline (Alfaro-Acha *et al.,* 2006:864). Grip strength is required to carry out many daily activities, owing to the vast range of daily activities that involve grip movements (Nicolay *et al.,* 2005:606). Hanten *et al.* (1999:198) conducted a study to determine the maximum grip strength of normal subjects between the ages of 20 and 64, and the results of both men and women between the ages of 55-64 years were significantly lower than that of men and women between the ages of 20-54 years. It was reported that older participants (≥65 years) make significantly slower movements than younger and middle aged adults between 20-40 years and 40-65 years (Smith *et al.,* 1999:1459; Frederiksen *et al.,* 2006). Dodds *et al.* (2013:796) indicated that increased levels of leisure time physical activity (LTPA) across midlife were associated with stronger handgrip strength between the ages of 60-64 years in both men and women. However, there is scanty data on the relationship between physical activity, body composition and handgrip strength among young and middle adults (Alrashdan *et al.,* 2016).

Measurements of physical performance may be used to identify elderly people who have functional limitations (Studenski *et al.,* 2003:321). According to Rikli and Jones (1997:257), a decline in physical activity later in life can easily result in physical limitations that can cause various problems with respect to disability. As such, the treatment of physical impairments should constitute a crucial step towards either preventing or slowing a progression towards functional limitation, disability and dependency (Rikli & Jones, 1997:257). The global recommendation on physical activity of the World Health Organization (WHO) suggests that adults between the ages of 18-64 years should accumulate at least 150 minutes of moderate intensity physical activity per week for durations of at least ten consecutive minutes (World Health Organization, 2016:31). Moderate physical activity are physical activity that get you moving fast enough or strenuously enough to burn off three to six times as much energy per minute as you do when you are sitting quietly, or exercises that clock in at 3 to 6 METs done on a scale relative to an individual’s personal capacity (World Health Organization, 2016:31).

Most of the studies that compared physical activity, body composition and handgrip strength were conducted in the urban areas of developed Western countries (Yancey *et al.,* 2004; Stenholm *et al*., 2008; Fogelholm, 2010). A limited amount of studies has focused on the role of physical activity in body composition and handgrip strength among adults of the North West in South Africa. It is, therefore, of great importance that a comparison is made between the physical activity, body composition and handgrip strength of adults from the North West in South Africa. In light of the relative scarcity of information available pertaining to the North West in South Africa, this research study endeavoured to answer the following research question:

- What is the relationship between physical activity, body composition and handgrip strength among South African young and middle adults living in the North West?

The above-mentioned research question provided valuable information in terms of recorded results and indicated a correlation between physical activity, handgrip strength and body composition among elderly in the North West. Moreover, the adult participants in the study experienced an added benefit – they became aware of their level of physical fitness in terms of their handgrip strength, their physical activity and body composition. Professionals in the field of Biokinetics and in the public health sector can make use of the results of this study when policies are formulated or intervention strategies are designed to improve the health of adults in the North West, South Africa.

1.3 Objectives

The objectives of the study were:

- To compare physical activity and handgrip strength in relation to BMI among male and female young and middle adults from the North West, South Africa.

- To determine a correlation between physical activity, body composition and handgrip strength among young and middle adults from the North West, South Africa.

1.4 Hypotheses

This study was based on the following hypotheses:

- Significant differences will exist between males and females when physical activity and handgrip strength are compared with the BMI of young and middle adults in the North West, South Africa.

- A significant positive correlation will exists between high levels of physical activity, low body composition and a greater handgrip strength among young and middle adults in the North West, South Africa.

In answering the research question, a cross-sectional study design was followed. Secondary data concerning physical activity, body composition, handgrip strength and their relationships were used, and were obtained during a Prospective Urban Rural Epidemiology (PURE) study done in the North West in 2015. Briefly, PURE was a large scale epidemiological study comprised of participants from low-income, middle-income and high-income countries around the world (Teo *et al.,* 2009). The two main objectives of PURE were to examine the relationship between societal influences; and the prevalence of risk factors and chronic NCD measured at baseline. Societal determinants were measured by an index of measures from each of the four domains of interest: built environment, food and nutrition policy, psychological/socioeconomic factors, and tobacco. The relationship between societal determinants and the incidence of chronic NCD events and on changes in rates of selected risk factors (e.g. smoking) were measured in the cohort component of the study.

1.5 Chapters of the dissertation

The dissertation will be submitted in article format, as approved by the North-West University Senate:

Chapters	
Chapter 1	Introduction
Chapter 2	Literature review: physical activity, body composition and handgrip strength among young and middle adults.
Chapter 3	*Article 1:* Differences in physical activity and handgrip strength in relation to body mass index in young and middle adults in the North West, South Africa. The paper was prepared in accordance to the requirements of the *African Journal of Primary Health Care and Primary Medicine.*
Chapter 4	*Article 2:* The relationships between physical activity, body composition, and handgrip strength among young and middle adults in the North West of South Africa. The paper was prepared in accordance with the requirements of the *African Journal of Primary Health Care and Primary Medicine.*
Chapter 5	Summary, conclusions, limitations, and recommendations.

The next chapter (Chapter 2) presents a literature review on physical activity, body composition and handgrip strength among young and middle adults. The reviewed literature served as the foundation for the two articles (Chapters 3 and 4) included in this dissertation.

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CHAPTER 2

LITERATURE REVIEW: PHYSICAL ACTIVITY, BODY COMPOSITION AND HANDGRIP STRENGTH AMONG YOUNG AND MIDDLE ADULTS

2.1 Introduction

Studies show consistent and progressive trends with regard to a decrease in physical activity with age (Rejeski & Mihalko, 2001:32; Leong *et al.,* 2016:539), and elderly individuals are the most affected (Miller *et al.,* 2000). Most elderly individuals tend to view physical activity or exercise as a recreational pursuit instead of medical therapy (Schutzer & Graves, 2004:1056). However, adults who are attempting to adopt and maintain a physical active lifestyle are persistently challenged by barriers that are often inescapable, such as aging, environmental conditions, disabilities (Seefeldt *et al.,* 2002:148) and a poor functional capacity (Silva *et al.,* 2013:134). The consequences of physical inactivity expose the elderly to high morbidity and mortality risk factors (Bannerman *et al.,* 2002:660; Silva *et al.,* 2013:133) as compared to the benefits associated with regular participation in physical activity (Warburton *et al.,* 2016: 807). According to Trost *et al.* (2002:1102), all older adults should be physically active, because regular physical activity – including aerobic activities and muscle strength activities – are essential for healthy aging. Participating in both aerobic activities and muscle strength activities also plays a role in the process of prevention and/or treatment of some diseases and disablements (Nelson, 2007:1098). A lifestyle characterised by moderate physical activity on a regular basis is important to the health and well-being of adults (Seefeldt *et al.,* 2002:161; Acree, 2006:5). Physical inactivity negatively influences health. Physically inactive individuals extremely vulnerable to continual weight gain and more disposed to some NCD risk factors, (Pietiläinen e*t al*., 2008:413; Martinez-Gonzalez *et al.*, 1999).

Overweight and obesity have a constant negative influence on physical activity (Trost *et al.,* 2002:1999). Regardless of age and gender in many studies, overweight and obesity remain threats to overall health and human development (Trost *et al.,* 2002:1999; Pietiläinen *et al.,* 2008:413). Obese or overweight individuals tend to fall below the level of physical activity that is needed to maintain a healthy lifestyle. Physical activity participation can, therefore, play a role in the prevention of threats, such as joint deterioration, muscles weaknesses and bone density Pietiläinen *et al.,* 2008:413). A sustained level of physical activity combined with regular moderate-vigorous intensity activity in the elderly is an ideal strategy to improve overall health (Hamer *et al.,* 2014:5). In most individuals, obesity occurs at a young age. Empirical research has revealed that the development of obesity during childhood has an association with adulthood obesity (Bourne *et al.,* 2002:159; Pietiläinen, 2008:412).The prevention of childhood obesity through regular physical activity should be encouraged during childhood to ensure that such a behavioural practice follows children spontaneously into adulthood (Malina *et al.,* 2004:601).

Daily physical activity is associated with enhanced muscle strength and good quality life (Haider *et al.,* 2016:3134). Improvement in muscular strength and function is accompanied by an improved functional status and a good quality life (Norman *et al.,* 2011:140). Likewise, muscle strength also decreases with advancing age. Handgrip strength is one of the measures used to determine muscle strength and muscle function (Norman *et al.,* 2010:138). It has been demonstrated as a superior outcome predictor both in healthy and ill individuals (Norman *et al.,* 2010:138). Furthermore, handgrip strength can also be used as a predictor of mortality and an indicator of risks associated with chronic diseases (Mattioli *et al.,* 2015:899). Even in the presence of chronic conditions, strength training can assist older individuals in maintaining a threshold of strength that is needed to perform functional tasks (Seguin & Nelson, 2003:146). Physical activity programmes for the elderly aim at maintaining or increasing handgrip muscular strength are crucial to balance the overall health of these individuals (Mattioli *et al.,* 2015:899).

This chapter focuses on reviewing available literature, the interrelationship between physical activity and handgrip strength in relation to some of the selected body composition measures that include: body mass index (BMI), waist-to-hip ratio (WHR), a skinfold test and bioelectrical impedance. The chapter provides a global overview of the status of physical activity, body composition and handgrip strength. An overview of factors is provided that are associated with physical activity, handgrip strength and body composition as individuals' age. This chapter further examines the important benefits of physical activity for body composition and muscular strength and ends with a summary.

2.2 Physical activity

Physical activity can be defined as any body movement produced by skeletal muscles that result in energy expenditure (Caspersen *et al.,* 1985126). Physical activity or leisure time physical activity includes walking, dancing, gardening, hiking, swimming, cycling and household chores that generally improve cardiorespiratory and muscular fitness, bone health, reduce the risk of NCD and depression (World Health Organization, 2016). Walking is a common, simple, accessible, convenient, inexpensive and the most popular form of physical activity for all adults (Ching *et al.,* 1996:29; Department of Health, 2000; Hallal *et al.,* 2012). Older adults who walk nine (9) kilometres at least once per week (equivalent to walking 10000 steps per day) have a greater probability of improving their functional abilities and reducing chances of functional limitations (Miller *et al.,* 2000:127; Pillay *et al.*, 2015:9). Age and gender continue to be the two most constant demographic determinants of physical activity (Trost *et al.,* 2002:1999; Bauman *et al.,* 2009:6). In general, males are found to be more physically active than women, and physical inactivity behaviour is higher among women than men (Troiano *et al.,* 2008:186: Bauman *et al.,* 2009:6; Oyeyemi *et al.*, 2013:174). Al-Zalabani *et al.* (2015:212) supports the previous mentioned statement by highlighting that individuals in the age group of 55-65 years have a high prevalence of physical inactivity when compared to other age groups.

Physical inactivity seems to have an indirect or direct effect on physical impairments and functional decline due to substantial human physical deterioration (Rikli & Jones, 1997:246). Physical activity appears to improve quality of life by enhancing the psychological well-being and improving the physical function of individuals who are suffering poor health (Bouchard *et al.,* 1994:8). In an attempt to maximise the effect of physical activity on quality of life, it is important to gain a broad understanding of the other factors that plays a role such as social environment in which individuals live in terms of the formal and informal social support systems (Taylor *et al.,* 2004). Hence other studies reported that certain environmental factors that do limit individuals from engaging in optimal physical activity (Humpel *et al.,* 2002:196; Kruger *et al.,* 2005:497; Bauman *et al*., 2012:262). Moreover, an understanding of the perception of threats and access to the environment in which individuals live should also be taken into consideration (Taylor *et al.,* 2004). To highlight risk factors that play a role, the urbanised population is increasingly exposed to fast foods and carbonated drinks (Puoane *et al.,* 2005:92). This widespread availability of inexpensive high calorie foods combined with a sedentary lifestyle is responsible factors contributing to a high mean BMI (Gutiérrez-Fisac *et al.,* 2004:713). An understanding of environmental factors that influence physical activity participation enhances, therefore, the effort to provide environmental interventions that may result in good health and decrease the prevalence of obesity and other NCDs (Flegal *et al.,* 2010:214).

2.2.1 Physical activity status among older adults

Worldwide, the participation in all types of physical activity has gradually improved in the past decade (Dishman & Buckworth 1996:63; Hallal *et al.,* 2012:247). However, there are limited data available regarding the prevalence of various types of physical activity in older adults and the percentage of older people whose physical activity participation meets the physical activity guidelines of the WHO (Sun *et al.,* 2013:15; WHO, 2016). According to Dumith *et al.* (2011:28), one out of five adults around the world does not meet the minimal levels of physical activity essential for health enhancement, and are therefore, considered being physically inactive. Stubbs *et al.* (2017:547) completed a world health survey based on 38 countries focusing on physical activity and anxiety, and reported that some countries with highest age-adjusted and sex-adjusted prevalence of low physical activity: United Arab Emirates (50.9%); South Africa (47.6%); Dominican-Republic (42.4%); and Namibia (40.5%).

According to the WHO, the global recommendation on physical activity for health is that adults between the ages of 18-64 years should accumulate at least 150 minutes of moderate intensity physical activity per week. Physical activity can be accumulated in bouts of at least ten consecutive minutes (Hoeger *et al.,* 2018:18).

Other countries, such as Australia, Canada, New Zealand, and the United States of America, were reported as having low levels of physical activity (Guthold *et al.,* 2008:489; Bauman *et al.,* 2009:5). . Reports from these countries are mostly from urban areas with relatively well-developed facilities for recreational activity and have a history of long-term promotion of exercise (Guthold *et al.,* 2008:489; Bauman *et al.,* 2009:5). Similar results were reported by Dumith *et al.* (2011:25) regarding the prevalence of physical inactivity associated with urban, wealthier and developed countries (27.8%)

with a significant difference (p=0.03). However, considerable proportions of walking (Hong Kong SAR, Japan, Spain, Taiwan) and vigorous activity (Belgium, Brazil, Taiwan) were also found in countries with low overall physical activity prevalence rates (Bauman *et al.,* 2009:5; Dumith *et al.,* 2011:25).

Furthermore, a higher prevalence of physical inactivity s were documented in large, urban and multi-ethnic population of Los Angeles (Yancey *et al.,* 2004:149). In this study, the ethnic differences in the self-perception of overweight and normal weight individuals were tested. African Americans and Latinos are significantly less likely to perceive themselves as overweight. As for African countries, more evidence of physical activity levels among elderly people is still needed to assist public health with strategies to improve the health and quality of life of older people. Literature on physical activity in African countries and South Africa is limited; and more studies are needed. The availability and accessibility of country-specific data and trends of physical activity levels will, therefore make it easy to monitor interventions, to promote physical activity and to improve public health (Bauman *et al.,* 2009:9). These data and trends will also provide a better understanding of the status of physical activity worldwide by providing useful baseline data as a source of information for researchers, public health practitioners and health providers (Hallal *et al.,* 2012: 247). Studies can thereafter be repeated to obtain population trends and comparisons of physical activity can then be made on a global scale (Bauman *et al.,* 2009:9).

2.2.2 Measures of physical activity in adults

The following figure 2, enlightens the physical activity assessment tools used measures of physical activity in adult according to Welk *et al.* (20017) and further explain each measure as a useful tool.

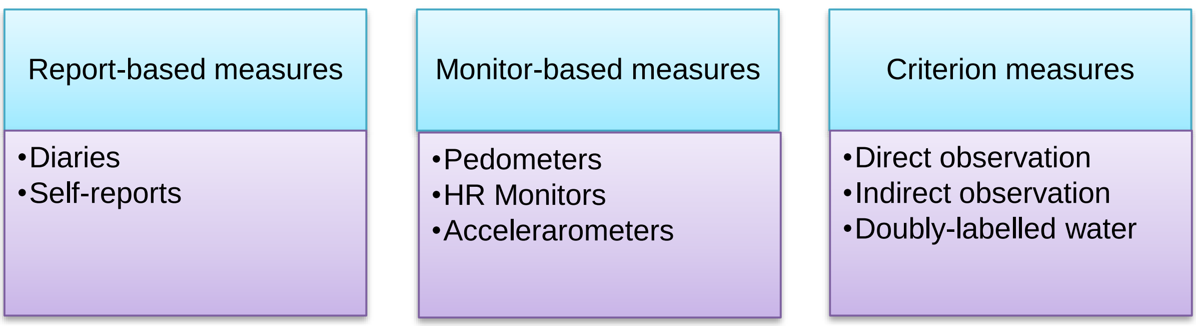

Figure 2-1: Physical activity assessment tools according to Welk *et al.* (2017)

An overview of the physical activity assessment tools used in the study is provided in the following section.

Report-based measures

Self-reports are used as a subjective measure that rely on the ability of participants to interpret and recall time that was spent performing physical activity in periods ranging from one day to three months. Self-reports are a convenient way to measure activity patterns in large populations. It can be self-administered in order to capture the interpretation of physical activity behaviour and the perception of participants (Welk *et al*., 200066; Welk, 2017:29).

Diaries provide participants with an opportunity to record physical activity performed throughout the day or right after it occurs. Measures of energy expenditure (e.g., kcals) are captured and information is provided on frequency, intensity, duration, type of physical activity, and the context of physical activity. Diaries can involve a disadvantage due to bias. For the participants to recall all of their activities done in one interview bias may be increased and they may fail to remember everything. However, the use of this measurement tool is less time-consuming takes; it takes approximately 1-20 minutes and recall questionnaires are easy to administer, interpret and understand (Welk, 2017:29).

Monitor-based measures

Activity monitors can be viewed as a modern physical activity research application. Most of these devices are used as internal accelerometers to obtain an objective indicator of the amount of movement being performed. Activity monitors provide an objective indicator of total body movement. Popular activity monitors, include the Actigraph and the GENEactiv. A disadvantage may be that participants have to wear a monitor for seven days and this can be viewed as a burden to some of the individuals. However, their capacity to perceive the magnitude and temporal characteristics of their movement is staggering (Welk *et al.,* 2000:67; Welk *et al.,* 2017).

Heart rate monitors capture the physiological response to movement of heart rate (usually expressed in beats per minute) and, reflect the level of stress executed on the cardiorespiratory system. These monitors track the number of beats per minute (bpm), which is (assumed to be) linearly related to oxygen consumption. Estimates of energy expenditure in kcal/day or kJ are provided and can be used to distinguish between different activities intensities. Heart rate monitors are more commonly used in combination with other measures (e.g., activity monitors) or for controlled laboratory-based studies, and particularly useful for monitoring activity associated with non-ambulatory activities, such as cycling or swimming, and for evaluating individual responses to physical activity (Trost, 2001:33; Stahl *et al.,* 2016:4; Welk *et al.,* 2017:30).

Pedometers are exclusively used to count the number of steps, as an indicator of movement. Pedometers can capture the frequency of movement (i.e., number of steps) but these tools can also produce estimates of the distance covered. The disadvantage of this tool centres on its inability to determine energy expenditure. However, it is simple to use and it is reliable and a valid tool to estimate the steps accumulated (at a walking speed) during the day (Welk *et al.,* 2017:31).

Criterion measures

Doubly-labelled water is the most accurate measure of total energy expenditure and allows for the energy expenditure of an activity to be determined. It also estimates the thermic effect of food and resting energy expenditure, if available. This measurement tool is very expensive and requires advanced expertise to administrate. It is, however, accurate in measuring total energy expenditure and its main value centres on the measurement protocols intended to provide a summary measure of overall free-living energy expenditure (Welk *et al.,* 2017:32).

Calorimetry measures the heat released due to the chemical process occurring when different body substrates are metabolised (e.g., carbohydrates, fat or protein). The method relies on the assumption that one litre of consumed oxygen is equivalent to known amounts of kcal depending on the substrate being metabolised. These measures have a particular gold standard assessment for lab-based and field-based studies on physical activity.

Direct observation is considered to be a gold standard method of physical activity assessment, because behaviour is directly observed. The advantage is that when physical activity is observed, a process or situation can be monitored/evaluated while it occurs. A probable disadvantage is observer bias (Welk *et al.,* 2017:32; Welk *et al.,* 2000:69; Taylor-Powell & Steele, 2008).

The present study made use of report-based measures – the International Physical Activity Questionnaire (IPAQ) – developed in 1997. The IPAQ was developed as a surveillance instrument to measure multiple domains of physical activity (Bauman *et al.,* 2009:2). It is a popular questionnaire that all countries can use that would permit comparability among countries on various domains of physical activity (Bauman *et al.,* 2009:2). The IPAQ consists of adequate properties for evaluating physical activity in healthy adults (Hagströmer *et al.,* 2006:758). Long and short questionnaires are available: the short questionnaire provides a global assessment of total physical activity, and includes a similar amount of job-related activities. The short questionnaire is more acceptable to both investigators and survey respondents. The IPAQ long questionnaire contains questions regarding both weekday and weekend sittings, it can reflect the "all-activity" nature of this measurement tool. However, the long questionnaire is difficult to answer (Craig *et al.,* 2003:1388; Hagströmer *et al.,* 2006:761). The observed concurrent validity (inter-method) coefficients between both the IPAQ questionnaires (Craig *et al.,* 2003:1385) suggest that both have equitable agreement. The IPAQ questionnaire evaluates four domains of physical activity (occupational, transport, household, and leisure) that are relevant for intervention planning. The content validity of the IPAQ is high, because the frequency, intensity, and duration of physical activity are assessed as well as sedentary behaviour (Craig *et al.,* 2003:1388).

Moreover, the IPAQ overcomes differences in other physical activity questionnaires with regard to physical activity measurements. It is broadly relevant to a wide range of countries and suitable for any mode of administration. It can, therefore be culturally adapted for a local or global population (Craig *et al.,* 2003:1389; Kurtze *et al.,* 2008:7). The IPAQ uses metabolic equivalent of task (MET) values as an indicator of activity intensity, which allows generally healthy adults to accumulate credit for the moderate or vigorous intensity activities they perform during the week. It is recognised that actual MET values can vary from individual to individual depending on a variety of factors (e.g., how they perform the activity, skill level, body composition), but the values provided in the compendium are sufficiently accurate for generally healthy adults between the ages of 18-65 years (Haskell *et al.,* 2007:6). The units used to quantify the score are derived from the concept of MET values. To determine the total physical activity level of individual participants, scores for vigorous, moderate and walking activities are calculated in MET-minutes per week by multiplying the MET intensity for each activity by the minutes per week that were spent in each activity. One MET value represents the energy that is expended while at rest and is the equivalent of maximal oxygen consumption (VO_2) in VO_2 of 3.5 ml/kg/min of VO_2.

2.2.3 Risks associated with physical inactivity

The ability to understand how to promote a more active lifestyle is important to the health of individual's worldwide (Bouchard *et al.,* 1994:5). Worldwide, 31.1% of adults are physically inactive. Dumith *et al.* (2011:28) reported that one out of five adults around the world does not meet the minimal level of physical activity necessary for health enhancement that entails at least 150 minutes of moderate intensity physical activity per week, according to the WHO. Physical inactivity or a low level of physical fitness are reported to cause 6-10% of the major NCDs, such as coronary heart disease, Type 2 diabetes, and breast and colon cancers (Bauman *et al.,* 2009:536; Lee *et al.,* 2012:227; Hallal *et al.,* 2012:248). Besides being exposed to chronic diseases, other common health problems associated with a lack in physical activity, such as musculoskeletal fatigue, bone loss, and joint stiffness, also play a devastating role (Bouchard *et al.,* 1994:5). By improving the awareness of the risks associated with an inactive lifestyle by highlighting some of the above-mentioned health problems, does not only promote a healthy lifestyle but also emphasise the negative impact inactivity has on human development (Ching *et al.,* 1996:29).

According to Kruger *et al.* (2007:327), participation in regular physical activity is associated with a better quality of life regardless of the BMI of individuals, as physical activity improves the overall health of individuals. Individuals with an excessive BMI value benefit when they regularly participate in physical activity. In the same study, Kruger *et al.* (2007:327) indicated that individuals who are more physically active, experience better health compared to inactive ones. All these reports highlight physical activity as the most popular approach to address overall health, weight management and reduces health risks associated with being overweight and/or obese (Patterson *et al.,* 2004:156). Physical activity is also used in clinical settings where adults with medical conditions are advised to stay active and engage in physical activity to stabilise their health to reduce the risk of developing other chronic diseases (Nelson *et al.,* 2007:1102). Individuals, who maintain a physically active lifestyle, participate at higher levels than the level recommended in the guidelines of the WHO. By improving their diet, they stand an even better chance of gaining further health benefits than those who are physically inactive.

Numerous studies (Dietz, 1996; Yancey *et al.,* 2004; Dumith *et al.,* 2011; Gardner *et al.,* 2016) have measured risks associated with physical inactivity and the prevalence of physical inactive older adults have indicated the important and the role of regular physical activity through the life span of human beings. According to McAuley *et al.* (2003), physical activity can also be influenced by social support.

2.2.4 The importance and benefits of physical activity in older adults

Virtually all older adults should be physically active to experience the benefits of a healthy active lifestyle and to avert the negative effects of inactivity on their health (Nelson *et al.,* 2007:1103). Studies have found that regular physical activity can be associated with a reduction in the risk of presenting with cardiovascular diseases, thromboembolic stroke, hypertension, Type 2 diabetes mellitus, osteoporosis, obesity, colon cancer, breast cancer, anxiety and depression (Bauman *et al.*, 2016: S276; Eriksen *et al.,* 2016:1439; Nelson *et al.,* 2007:1098; Strawbridge *et al.,* 2002). Participation in and maintenance of regular physical activity among the elderly are currently two of the most important strategies in preventing the onset or severity of many of the above-mentioned chronic diseases and to promote overall health (Ehlers *et al.,* 2018:11; Schutzer & Graves, 2004:1060). Furthermore, it was reported that an active lifestyle helps to increase the quality of life of older adults by stabilising functional ability and independence across their life span (Nelson *et al.,* 2007). The promotion of physical activity throughout the lifespan of individuals is justified on the basis of the direct benefits linked to physical fitness (Seefeldt *et al.,* 2002:152). The carryover of benefits can occur at an early age and depends on the level of physical activity maintained (Seefeldt *et al.,* 2002:152). A study by Bouchard *et al.* (1994:7) on physical activity, fitness and health provided evidence on the effects of physical activity on health and disease. These effects are illustrated in Figure 2-2:

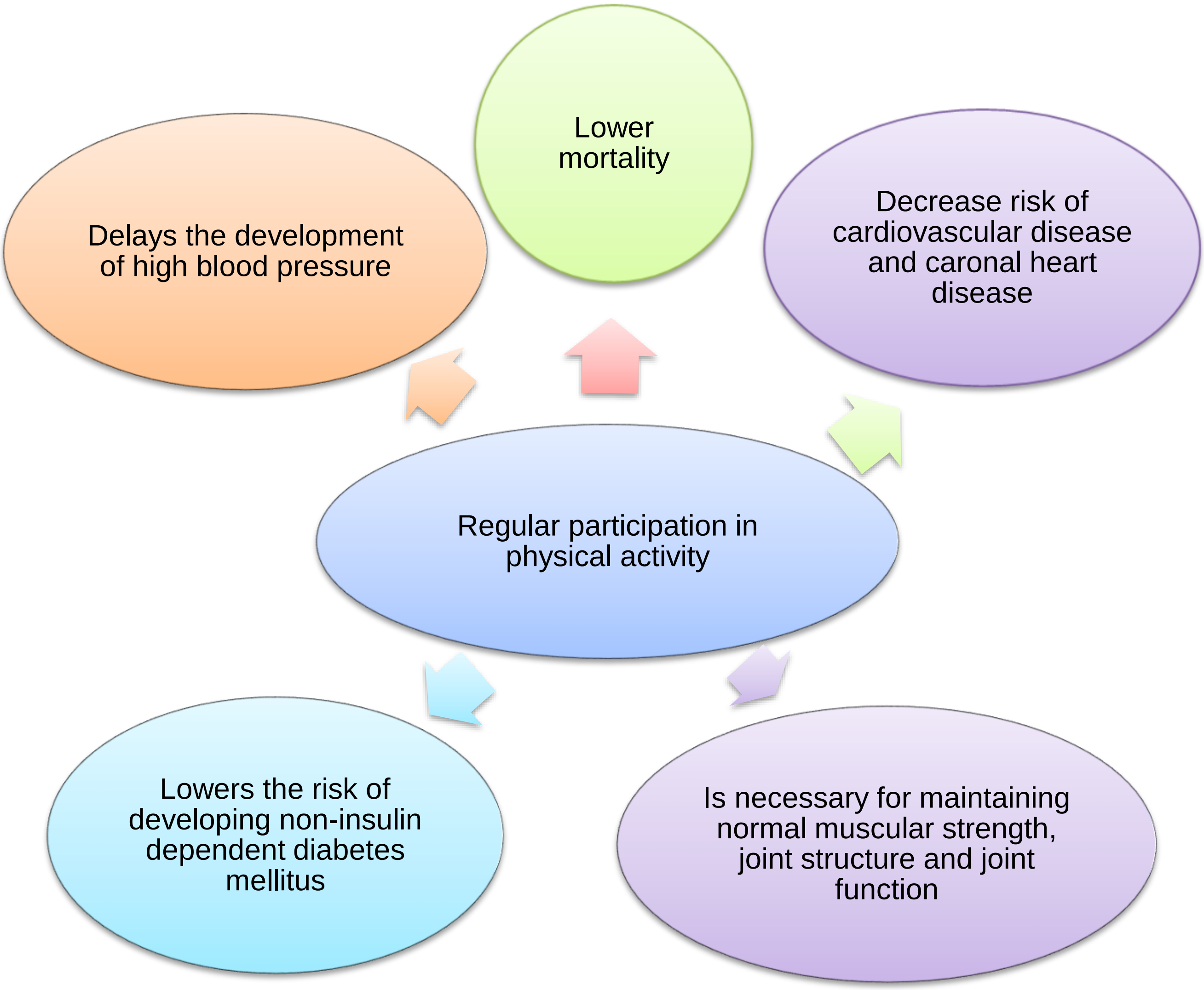

Figure 2-2: The outcomes of regular physical activity on health (adapted from the physical activity and disease model of Bouchard *et al. (*1994:7)

Regular participation in physical activity also appears to reduce depression and anxiety, improve mood and enhance the ability to perform daily tasks (Bouchard *et al.*, 1994:7).

2.3 Body composition

2.3.1 Measures of body composition

Body composition (BC) is the proportion of fat and fat-free mass in the body. Body fat can be found in muscle tissue, under the skin (subcutaneous fat) or around organs (visceral fat). Fat-free mass includes bone, muscle, organs, water and tissues in the human body. There are several methods used to measure BC depending on the information needed and the advantages of each method. Anthropometric measurements that are the most common methods used to obtain information for BC are BMI (body mass in kilogramme divided by height square (kg/m^2), waist to hip ratio (circumference of the waist divided by the hips), a skinfold test and bioelectrical impedance. These methods are used to determine body fat. Bioelectrical impedance determines the electrical impedance or resistance to the flow of an electric current through body tissues, which can then be used to estimate total body water to estimate fat-free body mass (Kyle *et al.,* 2004:1230; Mattsson & Thomas, 2006: R219; Ayvaz & Çimen 2011:66-67; Fosbøl & Zerahn 2015:90; Sergi *et al.,* 2017:596). BMI is a simple, reliable surrogate tool to measure body fat (Guo & Chumlea, 1999:1475s; Andreoli *et al.,* 2016:1467), and is the most frequently used measure of obesity in population health survey studies (Syddall *et al.,* 2003:560; Reilly *et al.,* 2018:1773; Andreoli *et al.,* 2016:1467). In the elderly, BMI may be considered as a simple method to attain markers of risks of functional impairment (Zoico *et al.,* 2004:240). However, with body composition, BMI cannot be used alone as a single measure, because the diagnostic performance of BMI in an intermediate range of body weight is limited, mainly because of its inability to discriminate between body fat percentage and lean mass (Romero-Corral *et al.,* 2008:965). With body composition it is, therefore, necessary to use other instruments as well, such as a skinfold calliper; waist circumference and waist to hip ratio for body fat distribution to determine body fat and lean body mass to provide more details about the body composition of individuals (Romero-Corral *et al.,* 2008:96). The combined measures can produce a useful measurement tool for monitoring the outcomes of diet and exercise programmes (McRae, 2010:161). In addition to that, when measuring body composition, the following factors should be considered:

- Tissue compressibility varies across gender, as women are found to be slightly less compressible than man due to differences in the distribution of fibrous tissue and blood vessels in the subcutaneous tissues ascribed to genetic, epigenetic and hormonal differences (McRae, 2010:159; Karastergiou, *et al.,* 2012:7).

- The correlation between BMI and the amount of body fat percentage varies among studies and ethnicity (Guo & Chumlea, 1999:1475s).

2.3.2 Body composition from different contexts

(a) International context

The prevalence of being overweight and/or obese continues to fluctuate globally and is influenced by racial and ethnic groups with regard to children, adolescents and adults regardless of gender (Ogden *et al.,* 2006:1555; Case & Menendez, 2009:271). Countries show differences in trends of obesity and in most countries, obesity remains a huge challenge (McPherson, 2014:729). The prevalence of being overweight and obese in the United States of America continues to be high with most females and elderly people either overweight or obese (30%) (Ogden *et al.,* 2006:1555; Flegal *et al.,* 2010:240). A study done by Gutiérrez-Fisac *et al*. (2004:721) on the prevalence of Spanish overweight and obese elderly individuals showed that approximately 80% of Spanish men and women older than 60 years of age are overweight and obese, and the observed prevalence was higher than in countries, such as the United States of America and England. A continual increase was found in overweight and obese Mexican Americans (Flegal *et al.,* 2004:5147) and Australians (Dalton *et al.,* 2003:560). Chukhraiev *et al.* (2017:563) who followed an integrative approach to reduce excess weight reported that in most countries individuals with excessive body weight is high especially in North America (the United States of America, Mexico and Canada); the Persian Gulf (Saudi Arabia, The United Arab Emirates and Egypt); Central Europe (Germany and Poland); and Southeast Asia (China, India and Indonesia). According to Flegal *et al.* (2012:496), a comparison of results between countries might indicate differences due to the sampling method and design used in each country.

(b) African countries

The prevalence of obesity is increasing in most African countries, particularly in individuals living in urban areas (Van der Merwe & Pepper, 2006:318; Abarca-Gómez e*t al.,* 2017:2636). Insufficient physical activity is a public health problem in most countries, especially in population subgroups of Africa that leads to a high prevalence in NCDs (Walker & Walker, 2001:369). Kruger *et al*. (2001:738) revealed that a high rate of obesity in African women is associated with an increase in their BMI level, skinfold thickness, WC and WHR, and shows a steady increase with age. Tuakli-Wosornu *et al.* (2014:11) also reported adult women in Ghana being at risk of obesity and other lifestyle-related health detractors. Currently, no fitness culture exists in Ghana. Compared with other countries, the prevalence of obesity in South Africa is extremely high in women and rising, especially those living in adjacent countries, such as Botswana, Namibia or Zimbabwe. The prevalence of obesity among African women far exceeds obesity in white women, and is reaching the statistics of African American women (Walker & Walker, 2001:369). They are many factors that play a role in the increase of obesity and overweight and can include human genetics, hormones and in some cases, diseases that prevent people from being physical active or even a lack of infrastructure (Loos & Bouchard, 2003:415; Van der Merwe & Pepper, 2006:319). Strategies to prevent or reduce risk factors associated with being overweight or obese in South Africa should, therefore be managed by establishing programmes and interventions within healthcare and community services (Kruger *et al.,* 2005:497).

2.3.3 The importance of measuring body composition in adults

Body composition can be divided into five levels: atomic, molecular, cellular, tissue-system and whole body. More than 30 body components can be evaluated in these five levels (Lohman, 1992; Wang *et al.,* 1992). The body consists of groups of constituents from each level – the sum of all atoms; the sum of all molecules; the sum of all cells; the sum of all tissues; the sum of all organs; and the sum of all systems (Mattsson & Thomas, 2006: R219). Ayvaz and Çimen (2011:62-63) highlighted that it is a commonly used clinical model to divides the body into fat mass and fat-free mass (FFM). Various techniques can be used to determine body composition, such as BMI, waist circumference, and percentage body fat (Lohman *et al.*, 1992). These measurement tools classify individuals as being overweight, obese, normal or underweight (Cole *et al.,* 2000).

Examples of body fat distributions in the body are abdominal body fat and/or visceral body fat, which is a type of body fat that is stored within the abdominal cavity. Abdominal fat is more strongly related to cardiovascular and metabolic risk factors. WC can be an estimated indicator of abdominal obesity and provides a feasible measurement to estimate glucose metabolic risks. Subcutaneous fat is less harmful, and can be viewed as a protective body wrap located under the epidermis, the outermost layer of skin. Callipers are used as an assessment of how much subcutaneous fat individuals have.

Excessive subcutaneous fat can lead to obesity (Sandeep *et al.,* 2010:633; Xu *et al.,* 2012:146-147).

Obesity has been recognised as a chronic disease by the World Health Organization (Van der Merwe & Pepper, 2006:315). The 1998 South African Demographic and Health Survey revealed that 31.8% of African women over the age of 15 years were obese (BMI $\geq$ 30 kg m^2) and 26.7% were overweight (BMI $\geq$ 25 to < 30 kg m^2) (Bourne *et al.,* 2002). BMI is, therefore, the most commonly used index to identify people who are obese and overweight, since it can be used to measure all categories of individuals (Chukhraiev *et al.,* 2017:563). When individuals should consider weight reduction that are at risk of NCDs, such as obesity and being overweight, consideration must be given to the fact that this problem is more threatening to some populations than others (Walker & Walker, 2001:370). Obesity cannot, therefore, be managed exclusively by individuals. Governments, communities, the media and the food industry all need to work together to modify the environment to create a supportive environment by making use of a multi-sectorial approach (Kruger *et al.,* 2005:497).

Obesity is a risk factor for many chronic conditions including diabetes, hypertension, high cholesterol, stroke, heart diseases, certain cancers and arthritis (Flegal *et al.,* 2004:5417; Flegal *et al.,* 2002:1726; Abubakari *at al.,* 2008:297). According to Dalton *et al.* (2003:562), one of the preferable measurement tools of obesity to predict the presence of cardiovascular disease in a clinical setting is WHR. WHR is a good indication of the accumulation of excess abdominal fat. However, more recently waist circumference alone has been suggested to predict intra-abdominal fat mass and total body fat (Dalton *et al.,* 2003:560). Elderly people differ from young adults and middle-aged individuals with regard to skinfolds and total fat (Durnin & Ranaman 1967:688). The use of the recommended skinfold calliper is not time-consuming or difficult; it should now be possible in hospitals, in general practices, and in laboratory work to obtain an objective assessment of the amount of fat in the body of individuals (Durnin & Ranaman, 1967:688). Obesity and Type 2 diabetes can be prevented by increasing physical activity, improving diet and by sustaining this lifestyle changes can reduce both body weight and the risk of diabetes (Mokdad *et al.,* 2003:78). A better understanding of the medical hazards associated with obesity should serve as a motivator to prevent excessive weight gain (Kruger *et al.,* 2001:739). Individuals with relatively high daily energy expenditure are less likely to gain weight over time compared with those who have low energy expenditures. The optional component of daily energy expenditure, especially for older people, is physical activity and the replacement of typically sedentary routines by various kinds of activity to increase energy expenditure (e.g., walking) (Haskell *et al.,* 2007:7). It is important not to focus only on the treatment of obesity but also to find strategies to prevent the onset of obesity (Jakicic *et al.,* 2002:3829s). Attempting to maintain a healthy body mass is influenced by a complex set of cultural, psychosocial and biological factors that make it difficult to accurately identify what the primary cause of obesity is for any individual (Haskell *et al.,* 2007:8). By knowing the initial factors that resulted in the condition, will help to develop or formulate strategies to treat the condition.

2.3.4 The role of physical activity in body composition

Physical inactivity levels are rising in many countries with major implications for the prevalence of NCD (World Health Organization, 2016:10). Inactivity can be described briefly as the time spent in sedentary behaviour characterised by less energy expenditure (Warburton *et al.,* 2016:499; Gardner *et al.,* 2016:103). Successful reductions in inactivity may, therefore provide the most effective approach to the treatment of obesity and the prevention of cardiovascular disease (Dietz, 1996:829-836). Furthermore, inactivity can be defined as a state in which bodily movement is minimal (Dietz, 1996:829). The promotion of physical activity in older adults should avoid ageism that discourages older adults from reaching their physical activity goals (Nelson *et al.,* 2007:1107). Body composition improvements with the aid of regular physical activity are an important pathway, as physical activity reduces cardiovascular and diabetes risks in older adults (Stewart *et al.,* 2005:17). Individuals who are physically active on a continual basis are less likely to develop health problems than sedentary individuals (Blair *et al.,* 2001: S396).

Physical activity is a useful method of controlling weight and health risks associated with obesity (Patterson *et al.,* 2004:156). According to Hughes *et al*. (2002:479), weight loss is associated with consistently higher levels of physical activity. For that reason, an increased level of physical activity is required for obese individuals who would like to lose weight. One of the healthy recommendations for older adult promotes aerobic activity to prevent unhealthy weight gain (Nelson *et al.,* 2007:1099). Compelling evidence shows that physical activity prolongs life and reduces the risk of coronal heart diseases, cardiovascular diseases, stroke and colon cancer (Blair *et al.,* 2001: S396). Furthermore, the risk for cardiovascular mortality is lower in individuals with a lower BMI and good aerobic fitness, compared with individuals with a normal BMI and a poor fitness record (Fogelholm, 2010:219; Stewart *et al.,* 2005:16).

Obesity-related health risks can be reduced considerably by increasing the amount of physical activity, and even more if aerobic fitness is improved simultaneously (Fogelholm, 2010:218). The behavioural strategies to implement regular physical activity and individual preferences for adults, according to Nelson *et al.* (2007:8), are that older adults with chronic conditions should develop an activity plan to address risk management issues related to their chronic conditions, activity limitations, abilities, risk for falling, and fitness levels. Strategies should also be employed to increase participation in physical activity. Acceptable and effective intervention programmes to treat obesity in black women, and to prevent excessive weight gain in young black women, should include aerobic activity to help prevent unhealthy weight gain (Nelson *et al.,* 2007:6; Kruger *et al.,* 2001:739). In addition, health professionals must also emphasise the impact of a balanced diet and physical activity for healthy weight loss, while maintaining a healthy weight should be a national priority (Mokdad *et al.,* 2003:79).

2.4 Handgrip strength

2.4.1 The importance of muscular strength as a body component of fitness

Muscular strength has been identified as a protective element independent of BMI, physical activity levels, aerobic capacity and muscle mass (Dimare *et al*., 2016:852). In men, a reduction in testosterone (testosterone levels were not the focus in this dissertation) is a contributing factor to the loss of muscular strength in adults (Taylor *et al.*, 2004. In women, an accelerated loss in muscle mass and gaining of fat due to menopause are indications that oestrogen plays a role in supporting muscle mass (Roubenoff & Hughes, 2000). Good muscular strength can be an indicator of better childhood health and good early life nutrition whereas poor muscle strength is an associated risk factor for diseases and an indicator of subclinical diseases (Rantenen *et al*., 1999). Low handgrip strength indicates subclinical diseases, such as diabetes and rheumatoid arthritis, which can later develop into clinical diseases and disability.

Therefore, diabetes and rheumatoid are is associated with increased loss of skeleton mass and it function .However, individuals with greater muscle strength during their midlife are at a lower risk of becoming disabled (Rantanen *et al.,* 1999:560).

Muscle strength plays an important role in the course of many common diseases and a loss in muscle mass due to aging is clinically important, as it leads to reduced strength and exercise capacity (Haider *et al*., 2016:3134; Tsekoura *et al.,* 2017:746). The effectiveness of muscle function is more important than the mere size of muscle. Gale *et al.* (2007:234) are of the opinion that poor handgrip strength predicts an increase in the mortality of men. Women in all age groups show a weaker performance than men (Barbosa *et al*., 2005:1182). Men and women differ, therefore, in their pattern of risk factors associated with grip strength (Sternäng *et al*., 2015:273). In women, lower handgrip strength is associated with many other life threatening conditions, such as bone mineral density and vertebral fracture (Dixon *et al*., 2005:644).

2.4.2 Handgrip strength as a measure of muscular strength in adults

Figure 2-3: A hand-held dynamometer model (T.K.K.54010 Takei)

Table 2-1: Validity and reliability of handgrip measures

Examples of instruments	Jamar	Martin vigorimeter	Harpended dynamomenter	Isometric strength testing unit
Units	**Kilogrammes (kg) or pounds of force (lbf)**	**Millimetres of mercury (mmHg) or pounds per square inch (psi) (lb/in2)**	**Kilogrammes (kg) or pounds of force (lbf)**	**Newtons of force (N)**
Validity of the test	• It is used to evaluate the maximum voluntary effort, of individuals based on a hand dynamometer test. • It accommodates various hand sizes.	• It measures the pressure exerted by the muscle.	• No much evidence has been presented on this device.	• It can measure strength and angle at the same time.
Reliability of the test	• It is reliable for determining peak torque angle if the mean of at least three repeated measurements is used. • It can be used to compare strengths of different subjects or one subject at different times.	• Easily compressed irrespective of hand size. • Reliable instrument, and can also be used for measurements of pulp pinch, tip pinch and lateral grips.	• Need specific grip position and the device must be calibrated.	• Excellent reliability of peak torque and total work measure.

(Le-Ngoc & Janssen, 2011:64; Neumann *et al.,* 2017:920; Robert *et al.,* 2011Solgaard *et al.,* 1984: 572)

The study made use of the hand-held dynamometer model (T.K.K.54010 Takei) to measure handgrip strength, as this model is considered to be appropriate for all individuals, because it does not require bearing weight and can be completed by almost everyone, including those who cannot walk (Barbosa *et al*., 2005:1182). Handgrip strength measurements can be used for the early screening of populations to identify those at high risk of physical disabilities related to low muscle strength (Rantanen *et al.,* 1999:559). Clinical meaningful changes in physical performance can contribute to clinical geriatric research in aging (Perera *et al.,* 2006:746). Measuring handgrip strength can, therefore be a useful instrument in a geriatric clinical practice to identify elderly people who are at risk for an accelerated decline in physical activity that can influence their daily living (Taekema *et al*., 2010:336). Performance measurements are used as indicators of health, as they provide basic information for medical diagnoses or when medical or restorative interventions are put in place (Studenski *et al*., 2003:321). Performance measurements can be an indication of current and future health, function and operations of older adults and are capable of reflecting important degrees of change in health, function and operations over time (Perera *et al.,* 2006:748).

Performance-based measurements provide useful introductory knowledge about the health of the elderly and risk progression to disability in older adults (Barbosa *et al.,* 2005:1182). The ability to measure physical performance in older adults may increase the quality of feedback provided to individuals, and the development of effective intervention programmes. Furthermore, performance measurements provide a better report for evaluating the physical performance improvements of individuals and programme effectiveness while enhancing the understanding of age-related declines (Rikli & Jones, 1997:422). Handgrip strength measurements predict functional limitations, functional decline and mortality in older adults (Dixon *et al.,* 2005:644). Functional limitations can be an indication of disability in older adults and in both men and women high muscular strength is associated with a lower prevalence of functional limitations (Brill *et al.,* 2000:414).

Variations in handgrip strength among individuals from different countries must be attributed differently. It is likely that differences in dietary quality, physical activity levels and social economy account in part for variations in muscular strength observed in different regions (Leong *et al.,* 2016:8). Handgrip dynamometry values must also be stratified by age and gender, because age and gender influence handgrip strength in a sense that a similar age group of males will show a higher muscular strength level than the same age group consisting of females (Incel *et al.,* 2002:255; Luna-Heredia *et al.,* 2004:255-256). Furthermore, males have a higher handgrip strength when compared to women (Moy *et al.,* 2011:49). Additionally, it is also necessary to stratify referral values by age, as values considered to be normal for a 70-year-old adult may be indicative of undernourishment in young adults (Luna-Heredia *et al*., 2004:255). A study by Budziareck *et al.* (2008:361) found that age becomes a marker after 60 years.

Since handgrip strength values vary according to age and gender, it is important to use different reference values for each group (Budziareck *et al.,* 2008). Differences in gender patterns necessitate meaningful research on handgrip and muscle strength in both genders. Adding to that, intervention strategies employed to improve muscle strength should also differ for gender groups, because men perform differently in physical activity compared to women (Sternäng *et al.,* 2015:271). However, age and gender are not the only factors that influence handgrip strength. The precision of handgrip strength measurements can be influenced by aspects, such as the allowance for hand size, hand dominance, posture, joint position, effort, encouragement, frequency of testing, the time of day; and training of assessors (Robert *et al.,* 2011:427).

2.4.3 The impact of physical activity and body composition on muscular strength

The human aging process leads to a decrease in physical activity (Lenardt *et al.,* 2016:90). Physical activity, muscle mass and strength decrease with age leading to sarcopenia (loss of skeletal muscle mass), which is associated with middle cognitive impairment (Jang & Kim, 2015:3912). Hand grip strength is a good indication of cognitive impairment and reduced grip strength may be a risk indicator for cognitive function even in individuals with a normal cognitive function. In addition, a decline in handgrip strength may represent an age-related change in physical function and frailty that can also contribute to cognitive decline and an increased risk of middle cognitive impairments (Jong & Kim, 2015:3912-3913). Low handgrip strength predicts an accelerated decline in activity concerning daily living, disability and can increase dependency in old age (Taekema *et al.,* 2010:335).

Physical inactivity in elderly is associated with lower handgrip strength, and is, therefore, an important contributing factor with regard to sarcopenia and aging (Lenardt *et al.,* 2016:90). Many age-related physiological changes that contribute to sarcopenia occur hormonally, neurologically, metabolically and behaviourally. Muscular strength training can, therefore have a positive impact on each of these physiological domains; it can be a useful and effective in any physical activity prescription for older adults (Sequin & Nelson, 2003:148). Furthermore, age-associated loss of skeletal muscle mass can cause functional impairments and disabilities – sarcopenia is, therefore, a significant public health problem (Jansses *et al.,* 2002:894). Strength training can reduce or delay functional limitations, physical impairments and falls in elderly people (Sequin & Nelson, 2003:142).

Regular physical activity also plays a role in decelerating the progression of functional limitations and disability in older adults (Acree *et al.,* 2006:4; Miller *et al*., 2000:1271). Lower levels of physical activity and lower levels of handgrip strength increase the chance of elderly individuals to become frail (Lenard *et al.,* 2016:91). Furthermore, a decreased handgrip strength, walking speed and energy expenditure may indicate early signs of frailty/weakness (Lenard *et al.,* 2016:90). After the age of 50 most individuals experience a decline in their handgrip strength (Mitsionis *et al.,* 2009:716). Interventions aiming at improving muscle strength are beneficial for functional health (Taekema *et al.,* 2010:355). Exercise programmes aiming to improve muscle strength can help prevent or slow cognitive decline in adults, especially those with a reduced handgrip strength (Alfaro-Acha *et al.,* 2006:864). Mattioli *et al.* (2015:888) reported no significant differences between the handgrip strength mean of active and inactive individuals' dominant and non-dominant hands.

Functional limitations, such as low handgrip strength performances, are associated with being overweight and/or obese and the elderly remains at risk for obesity (Zoico *et al.,* 2004:240). While researchers still make use of BMI as a predictor when evaluating the handgrip strength of individuals (Liao *et al.,* 2016:6), greater muscle strength can play a decisive role in reducing the odds of physical and functional limitations in obese elderly (Germain *et al.,* 2016:4). A higher handgrip strength performance is associated with a lower prevalence in physical activity with regard to daily living limitations and central obesity in the elderly (Germain *et al.,* 2016:3). Elderly individuals with low handgrip strength may have a low muscle mass and weaker physical strength and may result in poor handgrip strength measurements. Additionally, a lower muscle mass may be related to being undernourished or suffering a disease commonly associated with advancing age (Moy *et al.,* 2001:50).

2.4.4 Summary

From the reviewed literature, it is evident that physical activity is essential for health, regardless of age and gender. Additionally, literature revealed that daily physical activity improves general health by reducing life-threatening risk factors associated with a sedentary life style. Physical activity participation should always promote rather than threaten health. Forty year old adults and older fail to maintain the recommended amount of 60 minutes' physical activity recommended by the WHO due to their health conditions that courses limitation into their functional capacity. Older adults must, therefore be conscious about their physical capabilities by taking into consideration their health conditions to avoid risks associated with over exercising (World Health Organization, 2016). Moreover, in terms of age and gender, most studies revealed a pattern in the response to physical activity and functional performances with men being more physically active than women, but a decline in physical activity and functional performance is associated with increased age for both genders. Literature also revealed that there is a misconception regarding knowledge about obesity. Older people believe that being underweight is associated with diseases while being overweight as ideal for growing older and maintaining a sedentary lifestyle (Puoane *et al*., 2005:92). The belief of being overweight as an ideal body type for healthy adults is compounded by the idea that being thin /underweight is associated with HIV/AIDs. Moreover, inactive individuals tend to consume increased quantities of dietary fat that cause an imbalance between energy expenditure and energy intake. As such, an imbalance between energy expenditure and energy intake results into being overweight or obese. Obesity has been found to be associated with poor performance and other health risk factors.

Handgrip strength was found to decrease with age, mostly in females and older people when compared to other age groups. Lower handgrip strength is a result of poor muscular strength and a high BMI associated with physical inactivity. Poor muscular strength also prevents individuals from performing daily living activities that require muscle strength, such as lifting, carrying, and walking and these individuals tend to be frail. Furthermore, the ability to carry things and walk is needed on a daily basis. When individuals do not have this ability, it can be an indication of functional limitations that can be traced back to either being physical challenged, obese or frail. Literature also highlighted that all individuals must be educated about the importance of physical activity, body composition and muscular strength to increase knowledge and an understanding of the risk factors associated with a sedentary lifestyle and the importance of an active lifestyle from childhood.

The reviewed literature was limited with recent information regarding the prevalence of physical inactivity in Africa, especially in South African counties. The reviewed literature in this chapter forms part of the base for the chapters (3 to 6) to follow.

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CHAPTER 3

ARTICLE 1

Physical activity and handgrip strength in relation to body composition among adults from the North West Province in South Africa: the PURE-study

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3.1 Abstract

Background: Handgrip strength is an indicator of functional ability and nutritional status; which are related to physical activity status, especially among older adults. This study aimed to determine physical activity and handgrip strength in relation to body mass index among adults in the North West, South Africa. A total of 910 participants (men = 198; women = 490) between the ages of 35-70 years were part of a multidisciplinary Prospective Urban and Rural Epidemiological (PURE) study done in 2015. The participants completed a self-report international physical activity questionnaire-short form (IPAQ-SF). Handgrip strength was measured and body composition was determined by means of body mass index and waist circumference.

Results: The results showed that 29% of the men and 22% of the women were underweight p<0.001. Both the men and women were 22% overweight and 26% obese, respectively p<0.001. Men were more physically active, taller and underweight compared to women in all of the age groups. The women reported higher mean values for triceps, subscapular and waist circumference compared to the men. Regardless of age and gender, the underweight and normal weight groups reported higher physical activity levels and handgrip strength compared to the overweight and obese groups (p=0.43). Handgrip strength according to age groups was significantly (p<0.05) better in men (42-49 years; men 34.81 ± 11.13 kg versus women 26.29 ± 7.72 kg; 50-59 years; men 34.05 ± 9.19 kg versus women 25.12 ± 6.67 kg, 60-70 years; men 30.28

± 8.69 kg versus women 23.27 ± 6.44 kg) compared to women ($p<0.05$). The overweight and obese men performed poor in the minute spent in moderate-vigorous physical activity per week compared to the men in the other body mass index categories.

Conclusion: In the measurements of physical activity, handgrip strength and body composition significant gender and age groups differences were found. A large percentage of women were more overweight, less physically active and performed poorer in handgrip strength compared to the men. Additionally, both the men and women performed poorly when data were compared with the handgrip norm data. It's concluded that high physical activity increases handgrip strength. There should be a strong focus on women for strategic physical activity intervention, which should incorporate strength activities regardless of age.

Keywords: body composition, body mass index, handgrip strength, obesity, physical activity, waist circumference**.**

3.2 Introduction

Evidence regarding handgrip strength as a measurement of functional ability and other related health determinants, such as osteoporosis[1] and a loss in functional capacity, exists.[2,3,4] Additionally, handgrip strength is influenced by many factors[5], such as height, body mass index (BMI), nutritional status and physical exercise.[6,4] As age increases, muscle strength in general decreases.[7] In a study by CPP-Ile de France VI, an annual loss in grip strength of 1 kg for men younger than 75 years and 0.5 kg older than 75 years was reported with a mean annual loss of 0.3-0.4 kg in women.[8] An association between age-related loss of muscle mass and muscle strength can further explain a decrease in handgrip strength, because muscle weakness can possibly lead to a decrease in physical function, diminished physical activity, and sometimes immobility as well as a lack in the ability to perform normal daily activities.[9] Jang and Kim[7] reported that a poor handgrip strength has been associated with risk factors for cognitive dysfunction even in individuals with normal cognitive function, as it represents an age-related change in physical function, frailty, and an increased risk of middle cognitive impairments.

Massy-Westropp *et al*.[10] reported a non-significant positive correlation between handgrip strength and BMI in adult subjects (both females and males) between the ages of 30 and over 70 years. Similarly study by Lad *et al.*[11] revealed the highest handgrip strength in underweight (low BMI) females and the lowest in overweight subjects between the ages of 30 and over 70 years. Males, both overweight (31.16±2.06 kg) and underweight (33.1±4.29 kg), had a slightly lower handgrip strength than males with a normal BMI (33.33±2.58 kg) even though the results were not statistically significant. In both sexes, the lowest handgrip strength was found in subjects who belonged to the overweight (high BMI values) participant category.[11]

Kohl *et al.*[12] found physical inactivity as one of the leading causes of death in the world and one of the top pillars of non-communicable disease risk factors. Other studies have shown that physical inactivity levels are rising worldwide, and cause 6-10% of the major non-communicable diseases, such as coronary heart disease, Type 2 diabetes, and breast and colon cancers.[13,14] Walker *et al.*[15] identified NCDs related to obesity among Sub-Saharan women to be extremely high. Obesity was found to be more common in South Africa with a prevalence of obesity at 45.2% among adults aged between 60-69 years living in urban areas in comparison to other African countries and or rural settings.[16] Obesity usually indicates a history of inactivity that results in an increase in body fat, muscle weakness and a decrease in functional ability, especially in the elderly.[17,3,18] It has been well established that obese individuals need more muscle strength to move their body mass than individuals with a normal weight because, obese individual need more streght as compared to individuals with a normal weight.[19,20] Moreover, given the handgrip strength risks for mobility limitations, it is important to also investigate the distribution of handgrip strength among the normal weight, underweight, overweight and obese individuals in the adult population.[21]

Regular physical activity participation can, therefore, be a useful strategy for controlling body mass and health risks associated with obesity and muscle strength by preventing and eliminating risk factors associated with being physical inactive through exercise that might results to being overweight or obese.[22] Moreover, regular physical activity is associated with an improved quality of life regardless of BMI.[22,23] Properly developed muscle strength has been found to be essential for healthy aging,[24] while poor muscle strength due to loss of muscle mass is associated with fatal falls, which often may lead to increased mortality in older adults.[24,25,26,27]

Research on handgrip strength has been exclusively conducted in Western countries where a wealthy and sedentary lifestyle is all pervasive.[28,29] Developing countries are characterised predominantly by inequalities, malnutrition and manual labour. Handgrip strength mat, therefore, be a reflection of dietary composition and muscle training rather than ageing.[30] Additionally, the association between handgrip strength, ageing and mortality may be mediated by age-related diseases and attenuated when inequalities, malnutrition and manual labour are addressed.[28,31,30,32] The association of handgrip strength with muscle strength and nutrition has been established in a South African population. By determining handgrip strength related to body composition can, therefore, improve knowledge on the risk factors associated with a high BMI that can negatively impact handgrip strength, which is a determinant of muscle strength. The aim of this study was, therefore, to determine physical activity and handgrip strength in relation to BMI among adults in the North West, South Africa.

3.3 Methods

Study design and methods

A cross-sectional study design was followed during the Prospective Urban and Rural Epidemiology (PURE) study. The study took place from 2005 to 2015 in the North West, South Africa, and 910 participants formed part of the South African population. The data included in the study were based on information from 910 of the 923 participants who completed all the tests during the data collection in 2015.Thirteen of the participants were excluded due to incomplete data sets for use in the research study.

Participants

Males and females between the ages of 35-70 years participated in the study. For the purpose of this study and taking into consideration the published age-related norms (Table 1) for handgrip[33], the participants were categorised according to three age groups, namely 42-49, 50-59, and 60-70 years. Participants with cognitive disabilities were excluded from completing the physical activity questionnaire and those who were physically disabled, were excluded from measurements of height and weight, and their measurements were not taken for handgrip strength. The participants were approached for the follow-up interest study by door-to-door visits to all of the households whose members had participated in the original study and they were invited to a central clinic in both the urban and the rural area to participate in the collection process of new data. On the day of data collection, the lead researcher of the day collected the signed written informed consent forms and again reminded the participants that participation was completely voluntarily and that they could withdraw at any time (up to data analysis) without being penalised.

Anthropometric measurements and body composition

Anthropometric indicators of height, body mass, and waist circumference were measured by making use of the standard procedures described by the International Standard of Advancement of Kinanthropometry (ISAK).[33] BMI was calculated from body mass in kilogrammes divided by height in meter, squared (kg/m^2). BMI was categorised, according to the American College of Sport Medicine (ACSM)[34] cut points: BMI < 18 kg/m^2 = underweight; 18.5-24.4 kg/m^2 = normal; BMI ≥25-29.9 kg/m^2

= overweight; and BMI ≥ 30 kg/m² = obese. Body mass was measured to the nearest 0.1 kilogrammes of body mass by using a precision health scale manufactured by A and D Company of Tokyo, Japan. Stature (height) measurements were measured to the nearest 0.1 cm by making use of a calibrated stadiometer. Waist circumference measurements were determined to the nearest 0.1 cm using non-stretchable standard Lufkin tape measure (manufactured by Cooper Tools of Apex, North Carolina, United States of America). Waist circumference was categorised, according to the American College of Sports Medicine[34] categories, namely very low WC = WC<70 cm in women and <80 cm in men; low WC = WC 70-89 cm in women and 80-99 cm in men; high WC= WC 90-109 cm in women and 100-120 cm in men; very high WC = WC >110 cm women and >120 cm in men. Skinfold measurement of triceps and subscapular were measured in millimetres using a Harpenden skinfold caliper (Holtain Limited, United Kingdom) on the left hand side of the body. Measurements were taken three times at each site with 60 seconds between each measurement of which the average of the three measurements were used in the analysis.

Handgrip strength

Handgrip strength was measured by making use of a hand-held model (T.K.K.54010 Takei) dynamometer with the participants in a seated position with the elbow of the dominant hand to be tested flexed in a 90º degree angle. The dominant hand was tested twice and both values were recorded. In accordance with the procedures prescribed by the World Health Organization, the following steps were followed to obtain the handgrip strength measurements[14]: Set the dynamometer to zero (0); Check the fit of the dynamometer to the hand of the participant; Adjust the bar to rests on the phalanx bone of the index and ring finger; measure the dominant hand, inform the participant to grab the two pieces of metal, keeping the upper arm close with forearm at a 90º degree angle to the upper arm while squeezing the dynamometer as hard for three seconds; record strength in kilogrammes to the nearest kilogramme; Record “00” when an attempt was not made; Set the dynamometer to zero (0) and Repeat the procedure. The highest score for handgrip strength in kilogrammes was used in the analysis of the data as the handgrip value with 60-second rests between measurements.

Table 1: Handgrip strength norms, as determined by Zuboff [33]

HGS NORMS							
HGS Norms for Males				**HGS Norms for Women**			
AGE	Poor	Normal	Strong	**AGE**	**Weak**	**Normal**	**Strong**
10-11	< 12.6	12.6-22.4	> 22.4	**10-11**	**< 11.8**	**11.8-21.6**	**> 21.6**
12-13	< 19.4	19.4-31.2	> 31.2	**12-13**	**< 14.6**	**14.6-24.4**	**> 24.4**
14-15	< 28.5	28.5-44.3	> 44.3	**14-15**	**< 15.5**	**15.5-27.3**	**> 27.3**
16-17	< 32.6	32.6-52.4	> 52.4	**16-17**	**< 17.2**	**17.2-29.0**	**> 29.0**
18-19	< 35.7	35.7-55.5	> 55.5	**18-19**	**< 19.2**	**19.2-31.0**	**> 31.0**
20-24	< 36.8	36.8-56.6	> 56.6	**20-24**	**< 21.5**	**21.5-35.3**	**> 35.3**
25-29	< 37.7	37.7-57.5	> 57.5	**25-29**	**< 25.6**	**25.6-41.4**	**> 41.4**
30-34	< 36.0	36.0-55.8	> 55.8	**30-34**	**< 21.5**	**21.5-35.3**	**> 35.3**
35-39	< 35.8	35.8-55.6	> 55.6	**35-39**	**< 20.3**	**20.3-34.1**	**> 34.1**
40-44	< 35.5	35.5-55.3	> 55.3	**40-44**	**< 18.9**	**18.9-32.7**	**> 32.7**
45-49	< 34.7	34.7-54.5	> 54.5	**45-49**	**< 18.6**	**18.6-32.4**	**> 32.4**
50-54	< 32.9	32.9-50.7	> 50.7	**50-54**	**< 18.1**	**18.1-31.9**	**> 31.9**
55-59	< 30.7	30.7-48.5	> 48.5	**55-59**	**< 17.7**	**17.7-31.5**	**> 31.5**
60-64	< 30.2	30.2-48.0	> 48.0	**60-64**	**< 17.2**	**17.2-31.0**	**> 31.0**
65-69	< 28.2	28.2-44.0	> 44.0	**65-69**	**< 15.4**	**15.4-27.2**	**> 27.2**
70-99	< 21.3	21.3-35.1	> 35.1	**70-99**	**< 14.7**	**14.7-24.5**	**> 24.5**

Adapted from Zuboff[33]

Physical activity

Physical activity was measured by making use of the International Physical Activity Questionnaire Short Form (IPAQ-SF).[35] A study conducted among adults in 12 countries, including South Africa, aiming to test the reliability and validity of the IPAQ-SF, the IPAQ-SF demonstrated good evidence of one-week test-retest reliability (Spearman r = 0.70-0.97), and its criterion validity for total physical activity in minutes per week, as measured against accelerometer total counts was acceptable (Spearman r = 0.23).[35] The questionnaire was completed by means of interviews with the participants. The questionnaire requested information about physical activity participation and frequency: the number of days per week; and the duration of physical activity in terms of minutes per day of participation in vigorous and moderate activities and walking in bouts of at least ten minutes during the past seven days. Physical activity was obtained from the IPAQ-SF for the purpose of this study and was expressed in terms of minutes per week spent in vigorous physical activity, moderate physical activity, walking, sedentary activities and total physical activity. The units were used to quantify the score that was derived from the concept of the metabolic equivalent of task (MET). To determine the total physical activity level of each of the participants, scores for each vigorous, moderate, and walking activity were calculated in MET minutes per week by multiplying the MET intensity for each activity by the minutes per week that were spent in each activity. One MET represents the energy that is expended while sitting quietly at rest and is the equivalent of maximal oxygen consumption (VO_2) in VO_2 of 3.5 ml/kg/min of VO_2.

Statistical analyses

All analyses were done using the IBM SPSS version 24. To detect whether the data distribution was normal, the Kolmogorov-Smirnov test was used. Descriptive statistics were employed to determine mean and standard deviations for physical activity, body composition (body mass, BMI, WC, skinfold and handgrip strength). The frequency of percentages for categorical variables was also calculated. The Chi-square was calculated for the categorical variables, namely age group, physical activity and BMI, in order to determine the differences between the variables. An independent *t*-test was performed to determine the differences between the variables (age, height, triceps, subscapular, body mass, WC) of the male and female participants in the North West. An analysis of variance (ANOVA) was used to determine the difference between physical activity and handgrip strength, according to BMI categories. The level of significance was set at $p \leq 0.05$.

3.3.1 Results

The mean age of the total group of participants was 57.19 ± 6.93 years, with no significant ($p=0.35$) age difference between the male and female participants (Table 2). The men were significantly ($p<0.05$) taller and weighed less than the women. The women were significantly ($p<0.05$) heavier and fatter than the men. The results showed that the women had significantly ($p<0.001$) higher mean values for triceps skinfold (women=30.04 ± 11.52 mm; men=21.97 ± 9.56 mm) and subscapular skinfold (women=27.45±12.79 mm; men=17.51±10.19 mm) compared to the men. The women's handgrip strength was (24.70 ± 6.87 kg) significantly ($P<0.01$) poorer than that of the men (32.73 ± 9.53 kg). The results showed that the men (32.73 ± 9.53 kg) significantly ($p<0.05$) outperformed the women (24.70 ± 6.87 kg) in physical activity participation.

Table 2: The characteristics of the participants (total group), according to gender

	Total group				Men	Women	P-value for gender differences
	Mean	**SD**	**Min**	**Max**	**Mean ± SD**	**Mean ± SD**	
Age (year)	57.19	6.93	42.49	70.99	57.58±6.98	57.04±6.91	0.35
Body mass (kg)	64.19	16.32	30.60	109.90	59.32±13.60	66.15(16.90)	0.001
Height (cm)	159.28	9.75	15.00	185.80	166.42±7.18	156.39±9.15	0.001
BMI (kg/m^2)	25.30	6.47	11.47	39.93	21.39±4.77	26.88±6.40	0.001
WC (cm)	87.02	14.26	55.20	122.80	80.88±6.40	89.49±14.32	0.001
Triceps (mm)	27.72	11.579	4.00	65.80	21.97±9.56	30.04±11.52	0.001
Subscapular (mm)	24.59	12.90	3.10	68.20	17.51±10.19	27.45±12.79	0.001
Handgrip strength (kg)	27.01	8.54	5.77	66.20	32.73±9.53	24.70±6.87	0.001
Vigorous (min/wk)	57.12	142.55	0	1800	95.43±196.27	41.64±110.42	0.001
Moderate (min/wk)	293.82	295.81	0	1260	377.90±349.07	259.84±264.24	0.001
Walking (min/wk)	255.57	262.35	0	3360	292.53±173.89	273.69±134.78	0.001
Sit (min/wk)	279.11	147.22	60	720	292.53±173.89	273.69±134.78	0.17
MVPA/wk	350.93	374.34	.00	2700.00	473.33±466.69	301.48±317.19	0.001

BMI = body mass index; Vigmin/wk = vigorous intensity exercise in minutes per week; Modmin/wk = moderate intensity exercise in minutes per week; walkmin/wk = walking in minutes per week; Sit min/wk = sitting in minutes per week; MVPA = moderate to vigorous physical activity per week.

Results obtained for handgrip strength indicated that the men have a significantly ($p<0.05$) higher handgrip strength (32.73±9.53 kg) than the women (24.70±6.87 kg) across the age groups (42-70 years) with both the men and women showing a decrease in handgrip strength among the older adults (60-70 years old) (Table 3). The overall handgrip strength for both the men and women across all of the age groups is compared with the norm data, as presented in Table 1.

Table 3: Mean and standard deviations (SD) of handgrip strength for men and women in various age groups between 42-70 years

	All ages combined (42-70 years)		Age group 42-49 years			Age group 50-59 years			Age group 60-70 years		
	N	Mean(±SD)	N	Mean(±SD)	p-value of differences	N	Mean(±SD)	p-value of differences	N	Mean(±SD)	p-value of differences
Men	198	32.73(9.53)	34	34.81±11.13	<0.001	88	34.05±9.19	<0.001	76	30.28±8.69	<0.001
Women	490	24.70(6.87)	88	26.29±7.72		235	25.12±6.67		167	23.27±6.44	
Total	688	27.01(8.53)	122	28.66±9.56		323	27.55±8.43		243	25.46±7.90	

Out of the 688 participants, the results showed that 29% of the men and 22% of the women are underweight. The men and women are 22% overweight and 26% obese, respectively (Table 4). When the data were analysed according to gender, the results showed that the women were significantly ($p<0.001$) more overweight (33%) and obese (26%) than the men. More men (29%) are underweight compared to the women

(8%). The women were found to have a significantly ($p<0.001$) higher WC compared to the men.

Table 4: Descriptive frequency results of the participants' characteristics regarding the BMI and WC categories for the total group and by gender

Variable	Variables categories	Total group Freq/n (%)	Male Freq/n (%)	Female Freq/n (%)	p-value of the groups by gender differences (Chi-square)
BMI (kg/m^2)	Underweight	97 (14)	57(29)	40(8)	<0.001
	Normal	261(38)	100(51)	161(33)	
	Overweight	153(22)	25(12)	128(26)	
	Obese	177(26)	16(8)	161(33)	
	Total	688(100)	198(100)	490(100)	
WC (cm)	Low WC<70 cm	244(36)	108(55)	136(28)	<0.001
	Normal WC 70-89 cm	253(37)	73(37)	180(37)	
	High 90-109 cm	155(22)	17(8)	138(28)	
	Very high >110 cm	36(5)	-	36(7)	
	Total	688(100)	198(100)	490(100)	

BMI = body mass index; WC = waist circumference; Freq = frequency; (%) = percentage

The results showed that there is a significant difference ($p=0.05$) in the BMI categories according to age (Table 5). The normal and underweight groups are significantly taller than the other groups. The overweight and obese groups significantly ($p<0.001$) showed high mean values for body weight, BMI, WC, triceps and subscapular skinfolds compared to the underweight and normal groups. With regard to handgrip strength, the normal and overweight groups reported non-significant ($p=0.38$) higher handgrip strength values than the underweight and obese groups. In terms of physical activity, though not significant ($p>0.05$), the underweight and normal weight groups reported more time spent in vigorous, moderate, walking and moderate to vigorous physical activity per week compared to the overweight and obese groups.

Table 5: The body composition and physical activity of the participants, according to the BMI categories for the total group

		N	Mean	SD	P-value for group differences
Age (year)	Normal	261	57.30	6.88	0.05
	Overweight	153	58.22	6.86	
	Obese	177	56.96	7.28	
	Total	688	57.20	6.93	
Body weight (cm)	Underweight	97	43.83	6.22	<0.001
	Normal	261	54.90	6.55	
	Overweight	153	69.18	8.20	
	Obese	177	84.73	9.71	
	Total	688	64.19	16.32	
Height (cm)	Underweight	97	162.15	9.15	<0.001
	Normal	261	160.22	8.05	
	Overweight	153	158.25	14.22	
	Obese	177	157.20	6.62	
	Total	688	159.28	9.75	
BMI (kg/m^2)	Underweight	97	16.60	1.46	<0.001
	Normal	261	21.36	1.72	
	Overweight	153	27.22	1.40	
	Obese	177	34.24	2.82	
	Total	688	25.30	6.47	
WC (mm)	Underweight	97	68.30	6.07	<0.001
	Normal	261	79.10	6.65	
	Overweight	153	93.38	7.10	
	Obese	177	103.43	8.51	
	Total	688	87.02	14.26	
Triceps (mm)	Underweight	97	15.55	5.83	<0.001
	Normal	261	22.08	7.36	
	Overweight	153	31.72	7.76	
	Obese	177	39.27	9.80	
	Total	688	27.72	11.58	
Subscapular skinfold (mm)	Underweight	97	9.85	4.26	<0.001
	Normal	261	17.69	6.41	
	Overweight	153	29.49	8.49	
	Obese	177	38.61	10.39	
	Total	688	24.59	12.90	
handgrip strength (kg)	Underweight	97	26.36	8.92	0.38
	Normal	261	27.40	8.33	
	Overweight	153	27.61	9.22	
	Obese	177	26.30	8.00	
	Total	688	27.01	8.52	
Vig (min/wk)	Underweight	97	58.25	119.61	0.53
	Normal	261	62.74	146.58	
	Overweight	153	62.45	180.60	
	Obese	177	43.62	106.54	
	Total	688	57.12	142.55	
Mod (min/wk)	Underweight	97	309.12	305.95	0.30
	Normal	261	312.51	310.66	
	Overweight	153	257.71	257.07	
	Obese	177	289.07	298.42	
	Total	688	293.82	295.81	
Walk (min/wk)	Underweight	97	244.54	215.09	0.90
	Normal	261	264.90	258.62	
	Overweight	153	251.01	217.87	
	Obese	177	251.78	321.55	
	Total	688	255.57	262.35	
MVPA/wk	Underweight	97	367.37	371.47	0.43
	Normal	261	375.25	396.21	
	Overweight	153	320.16	376.15	
	Obese	177	332.68	339.75	
	Total	688	350.94	374.34	

BMI = body mass index; WC = waist circumference; Vigmin/wk= vigorous intensity exercise in minutes per week; Modmin/wk = moderate intensity exercise in minutes per week; walkmin/wk = walking in minutes per week; WHtR = Waist to hip ratio; MVPA = moderate to vigorous physical activity per week.

Though not significant (p=0.57), the obese men are older than the other groups (Table 6). The overweight and the obese men significantly (p<0.001) showed high mean values for body mass, BMI, WC, triceps and subscapular skinfolds compared to the underweight and normal groups. With regard to handgrip strength, the men categorised as overweight, reported slightly higher handgrip strength measurements than the men categorised as obese compared to the individuals classified as normal weight and overweight (p=0.03). In terms of physical activity, though not significant (p>0.05), the obese men performed poor in the moderate to vigorous activity per week compared to the men in other BMI categories.

Table 6: Body composition and physical activity, according to the BMI categories for men

		N	Mean	SD	P-value of the differences
Age (year)	Underweight	57	56.77	6.65	
	Normal	100	57.93	6.85	0.57
	Overweight	25	57.05	6.82	
	Obese	16	59.18	9.26	
	Total	198	57.58	6.99	
Height (cm)	Underweight	57	166.88	7.47	
	Normal	100	166.39	6.64	0.13
	Overweight	25	167.94	8.57	
	Obese	16	162.69	6.47	
	Total	198	166.43	7.18	
BMI (kg/m^2)	Underweight	57	16.71	1.35	
	Normal	100	20.90	1.71	
	Overweight	25	26.97	1.31	<0.001
	Obese	16	32.42	2.03	
	Total	198	21.39	4.78	
WC (cm)	Underweight	57	69.65	5.15	
	Normal	100	79.84	6.85	<0.001
	Overweight	25	96.27	5.27	
	Obese	16	103.44	7.37	
	Total	198	80.89	12.13	
Triceps (mm)	Underweight	57	16.26	5.91	
	Normal	100	21.13	8.02	
	Overweight	25	30.59	8.32	<0.001
	Obese	16	34.17	11.12	
	Total	198	21.97	9.56	
Subscapular skinfold (mm)	Underweight	57	10.19	4.21	
	Normal	100	16.38	6.68	
	Overweight	25	27.77	10.02	<0.001
	Obese	16	34.59	12.01	
	Total	198	17.51	10.19	
Grip strength (kg)	Underweight	57	30.22	8.81	
	Normal	100	32.89	8.69	0.03
	Overweight	25	36.41	11.37	
	Obese	16	34.96	12.05	
	Total	198	32.73	9.53	
Vigmin/wk	Underweight	57	79.65	143.61	
	Normal	100	97.70	172.66	0.21
	Overweight	25	160.00	368.07	
	Obese	16	36.56	61.34	
	Total	198	95.43	196.27	

Moderate min/wk	Underweight	57	359.30	341.50	
	Normal	100	402.50	368.25	
	Overweight	25	385.20	357.25	0.59
	Obese	16	279.06	223.28	
	Total	198	377.90	349.07	
Walk min/wk	Underweight	57	258.16	219.55	
	Normal	100	316.65	323.97	0.29
	Overweight	25	355.40	290.11	
	Obese	16	219.38	221.5	
	Total	198	296.84	286.35	
MVPA	Underweight	57	438.95	424.22	0.38
	Normal	100	500.20	470.19	
	Overweight	25	545.20	625.52	
	Obese	16	315.63	242.75	
	Total	198	473.33	466.69	

BMI = body mass index; WC = waist circumference; Vigmin/wk = vigorous intensity exercise in minutes per week; Mod min/wk = moderate intensity exercise in minutes per week; walk min/wk = walking in minutes per week; WHtR = Waist to hip ratio; MVPA = moderate to vigorous physical activity per week

There was a significant age difference (p=0.007) between the overweight and obese women and the normal weight and underweight women (Table 7). The overweight and the obese women significantly (p<0.001) showed high mean values for body weight, BMI, WC, triceps and subscapular skinfolds compared to the underweight and normal groups. With regard to handgrip, the overweight and obese groups obtained significant higher mean values in handgrip strength compared to the normal and overweight women. No significant differences (p>0.05) were reported in physical activity among the women.

Table 7: Body composition and physical activity, according to BMI categories for women

		N (490)	Mean	SD	P-value of the differences
Age (year)	Underweight	40	54.30	5.62	
	Normal	161	56.91	6.90	0.007
	Overweight	128	58.44	6.87	
	Obese	161	56.74	7.05	
Body weight (kg)	Underweight	40	39.73	4.92	
	Normal	161	53.01	5.83	<0.001
	Overweight	128	67.73	7.34	
	Obese	161	84.61	9.91	
Height (cm)	Underweight	40	155.42	6.84	
	Normal	161	156.39	6.30	0.90
	Overweight	128	156.35	14.36	
	Obese	161	156.65	6.40	
BMI (kg/m^2)	Underweight	40	16.43	1.62	
	Normal	161	21.64	1.67	<0.001
	Overweight	128	27.27	1.42	
	Obese	161	34.42	2.83	
WC (cm)	Underweight	40	66.38	6.80	
	Normal	161	78.65	6.51	<0.001
	Overweight	128	92.82	7.29	
	Obese	161	103.43	8.638	
Triceps skinfold (mm)	Underweight	40	14.54	5.63	
	Normal	161	22.67	6.88	<0.001
	Overweight	128	31.94	7.66	
	Obese	161	39.77	9.55	
Subscapular skinfold (mm)	Underweight	40	9.36	4.329	
	Normal	161	18.50	6.11	<0.001
	Overweight	128	29.83	8.16	
	Obese	161	39.01	10.18	
Grip strength (kg)	Underweight	40	20.86	5.62	
	Normal	161	23.98	5.96	<0.001
	Overweight	128	25.89	7.69	
	Obese	161	25.44	6.96	
Vigmin/wk	Underweight	40	27.75	63.06	
	Normal	161	41.02	123.40	0.86
	Overweight	128	43.40	105.80	
	Obese	161	44.32	110.12	
Modmin/wk	Underweight	40	237.63	232.45	
	Normal	161	256.61	254.39	0.29
	Overweight	128	232.81	226.17	
	Obese	161	290.06	305.41	
Walkmin/wk	Underweight	40	225.13	209.79	
	Normal	161	232.76	202.52	0.80
	Overweight	128	230.63	195.80	
	Obese	161	255.00	330.18	
MVPA	Underweight	40	265.38	251.17	
	Normal	161	297.64	320.13	0.38
	Overweight	128	276.21	288.94	
	Obese	161	334.38	348.45	

3.3.2 Discussion

The study aimed to determine the differences in physical activity and handgrip strength in relation to body composition in adults in the North West, South Africa. The findings showed that 29% of the men and 22% of the women are underweight while 22% and 26% of the men and women are overweight, respectively. The self-reported physical activity data reported underweight and normal groups associated with vigorous, moderate, walking and moderate to vigorous physical activity minutes per week compared to the individuals categorised as overweight and obese. In terms of physical activity, the results showed that adults in the underweight and normal groups performed better in their moderate to vigorous physical activity per week and walked more compared to the overweight and obese adults. Additionally, the results showed that the normal and overweight groups reported non-significant ($p=0.38$) higher handgrip strength values than the underweight and obese groups.

The South African National Health and Nutrition Examination Survey (SANHANES) of 2013[36] and a comparative study done with older adults of China, Ghana, Mexico, India, Russia and South Africa by Wu *et al.*[16] reported that South African men and women are overweight and obese. The presence of overweight and obese individuals in the present study is not surprising because previous studies in South Africa also noted this trend.[37,38] The observed prevalence of a double burden of obesity and underweight in the same sample population may be attributed to the poor socioeconomic status[37], and nutrition transition[39] associated with Westernised dietary intake.[38] The World Health Organization's global projection of non-communicable disease deaths will increase by 17% over the next ten years with the greatest increase to be expected in the African region (27%).[14] This observed prevalence in the current study necessitates strategic interventions aimed at the eradication of both obesity and underweight.

Men and women in the current study performed poor in handgrip strength compared to previous findings concerning South African men (age 50-59; 40.4±19.6 kg; and age 60-69: 35.8±19.6 kg) and women (age 50-59; 32.9±18.3 kg; and age 60-69: 31.8±17.9 kg) who participated in the Study of Global Ageing and Adults Health (SAGE wave 1) in 2008 by Ramlagan *et al*.[32] Additionally, the current sample performed poor when compared to a sample of 27,351 men and women aged 50 years and older from 11 European countries (mean maximum handgrip strength was 41.26 kg for men and 24.87 kg for women).[40] In a Japanese-American study done with men between the ages of 50-68 years, a maximum of 36.65 kg in handgrip strength was reported [40]. The handgrip strength from the Japane-American was much higher than what was reported in the current study by Ramlagan *et al*.[32] and Hairi *et al.*[40], this differences in the mean performance may be explained by the sample size used in their study.

Improved muscle strength and regular physical activity are important factors for quality of life, cardiovascular health and the risk of conditions characterised by being either overweight or obese is minimised – these conditions have a negative impact on the health of elderly individuals.[41,42] The effect of obesity on quality of life was a great concern in this study. The normal and overweight groups, though not significant, outperformed the underweight and obese groups. However, the overweight group slightly outperformed the obese men compared to the normal and overweight groups. The performance of the overweight group may be attributed to the fact that the absolute handgrip strength may not be hindered. Handgrip strength ought to decline when the body fat percentage increases and not when the body weight increases.[11]

In terms of physical activity, though not significant ($p>0.05$), the underweight and normal groups performed better in vigorous, moderate, walking and moderate to vigorous physical activities per week compared to the overweight and obese groups. Underweight and/or normal BMI may, therefore, be a result of individuals being regularly physically active, because consistent participation in regular physical activity increases physical activity abilities and lowers the risk of obesity and being overweight.[17,22] Other studies may explain the insignificance of physical activity, according to the BMI categories based on the inability of BMI to distinguish between total body fat percentage and lean body mass.[43] However, physical activity remains a trusted tool to decelerate the progression of function limitations or disability and acts as a prevention or treatment tool in some diseases and disablements compromised by poor muscle strength, obesity and being overweight.[44,45,27] Both the men and women in the current study, though outperformed by larger South African and European samples, performed better than the Ghana sample (men: 31.3±8.7 kg; and women: 23.6±5.9 kg).[30] The poor performances of Ghanaian men and women (handgrip strength) can be linked to their lack in a fitness culture[46] Unfortunately, this notion was not applicable to the adult participants in the current study. In terms of physical activity, the men performed better than the women in vigorous, moderate and walking minutes per week with a high moderate to vigorous physical activity per week mean value. The findings are in agreement with previous studies.[17, 48,47,49] These outcomes on physical activity portray women as being less adequate in physical fitness and strength compared to men from Denmark.[50]

This study had several strengths and limitations that should be considered when interpreting the data. The strength of the study included a large sample of both men and women in South Africa. The second strength is that the study was a cross-sectional study and provided baseline data that will enable further research on the exploring of handgrip strength. These findings can, therefore, be used as baseline data in future longitudinal study approaches. The third strength of the study is that the international standardised IPAQ-SF was used. This permitted comparability among countries on various domains of physical activity. This was a cross-sectional study and no comparisons or causal relationships could be drawn. The other limitation is that the nutritional status, culture, and environment factors were not registered. The possible effect of these factors on handgrip strength nor body composition was not studied and handgrip strength was not assessed as a predictor of mortality and undernourishment. Future researchers should focus on these factors that have an impact on physical activity, body composition and handgrip strength among adults.

3.3.3 Conclusion

The study found a decrease in physical activity with increased age and gender differences were highlighted – the women were more overweight and physical inactive compared to the men who were classified as underweight and physically active. The men were highly active and performed better than women in handgrip strength. The participants were classified as overweight and obese, and the older participants performed poor in handgrip strength compared to those classified as underweight and normal. Given the health implication of these findings, strategic intervention programmes geared to the reduction of underweight, overweight and obesity as well as increasing physical activity are urgently needed.

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CHAPTER 4
ARTICLE 2

The relationships between physical activity, body composition and handgrip strength among adults from the North West, South Africa: the PURE study

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4.1 Abstract

Background: Handgrip strength is associated with body mass and physical activity, and as a marker of muscle quality. However, scant information exist on the relationships between physical activity, body composition and handgrip strength among adults in South Africa. Therefore, this study reviewed relationships between physical activity, body composition, and handgrip strength among adults in the North West, South Africa.

Methods: A total of 688 men (n=98) and women (n=490) between the ages of 35-70 years were included from the 2015 measurement wave of the Prospective Urban and Rural Epidemiological (PURE) study. Physical activity was assessed by conducting interview by making use of the International Physical Activity Questionnaire-Short Form (IPAQ-SF). Standard protocols were used to determine handgrip strength, height and weight. Subsequently, body mass index – a measure of body composition − was calculated by dividing weight and height square. Descriptive statistics were used to determine the characteristics of the participants. Significant differences between physical activity, handgrip strength and body mass index were analysed with independent t-tests and an analysis of variance. Spearman correlation coefficients were employed to determine the relationship between physical activity, body mass index and handgrip strength.

Results: Overweight was reported in 22% and obesity in 26% in all of the participants. The women were significantly (p<0.001) more overweight (26%) and obese (33%) compared to the men (13% overweight and 8% obese). Sixty percent (60%) of the participants reported sufficient physical activity per week (p<0.001). Seventeen percent (17%) of the men and 27% of the women were physically inactive per week (p<0.001). Handgrip strength performance significantly (p<0.05) differed according to age. Generally, the handgrip strength of the participants in the study was poor compared to available handgrip strength norms. The participants aged younger than 50 years outperformed the older groups with men being stronger than women. The men and women who were sufficiently active per week significantly (p<0.05) performed better than the other groups. A positive association was found between handgrip strength and body mass index. A negative correlation was found between moderate to vigorous physical activity per week (r= -0.12; p=0.001) and age. Handgrip strength in both the men (r= -0.23; p= 0.001) and women (r= -0.18; p=0.000) correlated negatively with age.

Conclusion: Overweight and obesity were highly prevalent in the adults with the women more affected than the men. The older adults were less active than the younger adults with the men performing more moderate to vigorous physical activity per week. Although handgrip strength was low when compared with the handgrip strength of the participants, the men reported higher mean values than the women. An increase in age was associated with a decrease in moderate to vigorous physical activity per week and handgrip strength. Given the health implications of the current findings, strategic interventions aimed at the reduction of obesity and physical inactivity are needed. As such, the study recommends an urgent strategic physical intervention in older men and women to improve their quality of life.

Keywords: Physical activity, handgrip strength, obesity, body mass index.

4.2 Introduction

Studies revealed significant associations between handgrip strength, physical activity[1] and body mass.[2] In addition, a loss in muscle mass is significantly associated with age.[3,4,5] Worldwide, 31.1% of adults are reported to be physically inactive. Physical inactivity is linked to noncommunicable diseases (NCDs) such as, Type 2 Diabetes, Mellitus a cancers.[6,7] Some studies and reports[8,9,10] indicates that 20% of the global populace within the age range of the 18 to 64 comply with the minimum physical activity guideline.[11]

Studies have also indicated that obese individuals suffer from NCDs from early in their lives and carries it to adulthood.[12,13,14] Overweight and obesity are identified as a constant negative influence on physical activity, regardless of age.[15,14] In the early stages of life, the prevention of obesity through regular physical activity should be encouraged and should be maintained, as this condition can track spontaneously into adulthood.[16] Waist circumference is used as the most surrogate measure of abdominal or visceral adiposity in clinical and public health settings when working with obesity or overweight.[17] Kob et al.[18] reported that muscle and architecture which is physical arrangement of muscle fibre at the macroscopic level that determines a muscles mechanical function (e.g., infiltration of intramuscular fat) are related to lower physical performance and function. A study by Benavides-Rodriguez et al.[19] reported a partial mediation of anthropometric parameters (body mass, body mass index and waist circumference) in an association between handgrip strength and muscle mass. Both body mass index (BMI), waist to height ratio (WHtR) and waist circumference (WC) measures are found to be associated with all-cause mortality, diabetes mellitus, cardiovascular morbidity and mortality.[20,21,22,23,24]

Daily physical activity is reported to be associated with muscle strength, indicating one's quality of life.[25] Conversely, a low handgrip strength is associated with being overweight, having excessive body fat and a high BMI.[26] therefore physical activity is essential in improving muscle strength and decrease excessive body weight Handgrip strength is a proxy measurement tool for muscle strength and muscle function, as it demonstrated to be a superior outcome predictor in healthy and ill individuals.[27] Poor muscle strength plays, therefore, a significant role in reducing the odds of physical and functional limitations with age, and more so in obese elderly.[28] When it comes to handgrip strength and BMI, an improvement in muscular strength and functional status can be achieved by regular physical activity, which plays a similar role in reducing the odds of being overweight or obese, and these conditions can track spontaneously from childhood into adulthood.[27] Regardless of age, good muscular strength and a low BMI can be indicators of better health and good early life nutrition; whereas poor muscle strength and a higher BMI are viewed as associated risk factors for diseases and subclinical diseases.[29]

Poor muscle strength has a negative effect on the overall health and human development or growth.[15,14] A lower muscle mass can be the result of being undernourished or impaired by chronic diseases commonly associated with advancing age.[30] Available findings on the relationships between handgrip strength, body composition and physical activity also show the effect of gender with men often outperforming women in handgrip strength. More physically active women are prone to be classified with a lower BMI while low levels of physical activity are an indication of extreme vulnerability to continual weight gain[14] when women are compared to men.[31,32] Kruger *et al.*[12], identified obesity is associated with advancing age in African women and in South Africa.[12] Physical activity, muscle mass and strength decrease with age and these decreases lead to sarcopenia (a loss in skeletal muscle mass) associated with middle cognitive impairments.[12] Regular participation in physical activity can delay risk for sarcopenia by improving and maintaining muscle mass and strength.

In spite of available information about the relationships between physical activity, handgrip strength and body composition, little information on these relationships is available in Africa, especially in the North West, South Africa. A better understanding of the relationships between these variables can enhance the motivation for participating in physical activity and public health when improved intervention programmes can treat and minimise the risks associated with physical inactivity. The measurement of handgrip strength as a predictor of functional limitations, functional decline and mortality in older adults is extremely useful. The purpose of this study was, therefore, to determine the relationships between physical activity, handgrip strength and body composition among adults in the North West, South Africa.

4.3 Methods

Study design, participants and methods

A cross-sectional study design was performed on a total of 688 (men, n=198 and women, n=490) between the ages of 35-70 years from the 2015 data collected in the North West Prospective Urban and Rural Epidemiological (PURE) multidisciplinary international study. For the purpose of this study and taking into consideration the published age-related norms (Table 1) for handgrip[26], the participants were categorised according to three age groups, namely 42-49, 50-59, and 60-70 years. The methods and population characteristics of the PURE study are not included in this article.[33,34] Briefly, the design of the PURE study was based on selected countries to achieve substantial socioeconomic heterogeneity. For reasons of feasibility, the PURE study undertook comparable sampling from all countries worldwide or from regions within countries. At the start of the study, selected countries were categorised according to high-income (Canada, Sweden, and United Arab Emirates); upper middle-income (Argentina, Brazil, Chile, Malaysia, Poland, South Africa, and Turkey); lower middle-income (China, Colombia, and Iran); and low-income (Bangladesh, India, Pakistan, and Zimbabwe) countries. The categories were further grouped based on country-income levels with a similar amount of participants. Participants from high-income and upper middle-income countries were grouped together as participants from high-income countries.[33,34] The method of approaching households differed among countries but was designed to avoid biases based on levels of risk factors or the prevalence of diseases. Households could participate in the study if at least one member of the household was between the ages of 35-70 years and the household members intended to continue living at their current address for another four years. Only individuals who provided written informed consent were enrolled.

Anthropometrics and body composition

Anthropometric measurements of height, body mass and WC were obtained, according to standard procedures described by the International Standard of Advancement of Kinanthropometry (ISAK).[35] Body mass was measured to the nearest 0.1 kilogrammes of body mass by making use of a precision health scale manufactured by A and D Company of Tokyo, Japan. Stature (height) measurements were recorded to the nearest 0.1 cm using a calibrated stadiometre. BMI was calculated from body mass in kilogramme divided by height in meter squared (kg/m^2). BMI was categorised according to the American College of Sport Medicine (ACSM) cut points. BMI < 18 kg/m^2 = underweight; 18.5-24.4 30 kg/m^2 = normal; BMI 25-29.9 kg/m^2 = overweight; and BMI ≥ 30 kg/m^2 = obese. WC measurements were recorded to the nearest 0.1 cm by making use of a non-stretchable standard Lufkin tape measure manufactured by Cooper Tools of Apex, North Carolina, United States of America. The WC risk measurements were categorised according to very low (WC<70 cm in women and <80 cm in men); low (WC 70-89 cm in women and 80-99 cm in men); high (90-109 cm in women and 100-120cm in men); and very high (>110cm women and >120cm in men). Skinfold measurement of triceps and subscapular were measured in millimetres using a Harpenden skinfold calliper (manufactured by Holtain Limited, United Kingdom) on the left hand side of the body. Measurements were taken three times at each side with 60 seconds between each measurement of which the average score of the three measurements were used in the analyses of the percentage body fat.

Handgrip strength

Handgrip strength was measured using a hand-held model (T.K.K.54010 Takei) dynamometer with the participants in a seated position with the elbow of the dominant hand to be tested flexed in a 90º degree angle. The dominant hand was tested twice and both values were recorded in kilogramme. In accordance with the procedures prescribed by the World Health Organization, the following steps were followed to take the handgrip strength measurements[9]:

Set the dynamometer to zero (0); Check the fit of the dynamometer to the hand of the participant; Adjust by turning the handle to move it up or down, so that the bar rests on the phalanx bone of the index and ring finger; Ask the participant to use his or her dominant hand to grab the two pieces of metal, keeping the upper arm close to his or her body and holding his or her forearm at a 90º degree angle to the upper arm; When ready, ask the participant to squeeze the dynamometer as hard as he or she can for three seconds; Read the dial at eye level and record strength in kilogrammes to the nearest kilogramme; Record “00” whenever an attempt was not made; Set the dynamometer to zero (0) and repeat the test with the dominant hand; Repeat the procedure. The highest score for handgrip strength in kilogrammes was used in the data analysis. Data from this study were compared with the handgrip strength norms presented in Table 1.

Table 1: Handgrip strength norms, as determined by Zuboff [26]

Handgrip strength norms							
HGS norms for males				**HGS norms for women**			
AGE	Poor	Normal	Strong	**AGE**	**poor**	**Normal**	**Strong**
10-11	< 12.6	12.6-22.4	> 22.4	**10-11**	**< 11.8**	**11.8-21.6**	**> 21.6**
12-13	< 19.4	19.4-31.2	> 31.2	**12-13**	**< 14.6**	**14.6-24.4**	**> 24.4**
14-15	< 28.5	28.5-44.3	> 44.3	**14-15**	**< 15.5**	**15.5-27.3**	**> 27.3**
16-17	< 32.6	32.6-52.4	> 52.4	**16-17**	**< 17.2**	**17.2-29.0**	**> 29.0**
18-19	< 35.7	35.7-55.5	> 55.5	**18-19**	**< 19.2**	**19.2-31.0**	**> 31.0**
20-24	< 36.8	36.8-56.6	> 56.6	**20-24**	**< 21.5**	**21.5-35.3**	**> 35.3**
25-29	< 37.7	37.7-57.5	> 57.5	**25-29**	**< 25.6**	**25.6-41.4**	**> 41.4**
30-34	< 36.0	36.0-55.8	> 55.8	**30-34**	**< 21.5**	**21.5-35.3**	**> 35.3**
35-39	< 35.8	35.8-55.6	> 55.6	**35-39**	**< 20.3**	**20.3-34.1**	**> 34.1**
40-44	< 35.5	35.5-55.3	> 55.3	**40-44**	**< 18.9**	**18.9-32.7**	**> 32.7**
45-49	< 34.7	34.7-54.5	> 54.5	**45-49**	**< 18.6**	**18.6-32.4**	**> 32.4**
50-54	< 32.9	32.9-50.7	> 50.7	**50-54**	**< 18.1**	**18.1-31.9**	**> 31.9**
55-59	< 30.7	30.7-48.5	> 48.5	**55-59**	**< 17.7**	**17.7-31.5**	**> 31.5**
60-64	< 30.2	30.2-48.0	> 48.0	**60-64**	**< 17.2**	**17.2-31.0**	**> 31.0**
65-69	< 28.2	28.2-44.0	> 44.0	**65-69**	**< 15.4**	**15.4-27.2**	**> 27.2**
70-99	< 21.3	21.3-35.1	> 35.1	**70-99**	**< 14.7**	**14.7-24.5**	**> 24.5**

Adapted from Zuboff [26]

Physical activity

Physical activity was determined with the International Physical Activity Questionnaire - Short Form (IPAQ-SF).[25] The questionnaire was completed by means of interviews. The participants were requested to report on their time, frequency and duration of physical activity in terms of minutes per day of participation in vigorous and moderate intensity activities and walking in bouts of at least ten minutes during the past seven days. For the purpose of this study physical activity was expressed in terms of minutes per week spent in vigorous physical activity, moderate physical activity, walking, moderate to vigorous physical activity (MVPA), sedentary activities and the total of physical activity. Physical activity was reported as metabolic equivalent task (MET) minutes/week.

Statistical analyses

All the analyses were done using the IBM SPSS version 24 statistical software. Normality distribution of the data was determined with the Kolmogorov-Smirnov test. Descriptive statistics were employed to determine the characteristics of the participants and to report the mean, minimum, maximum standard deviations and frequency distributions were calculated in percentages for physical activity, body composition and handgrip strength. An independent t-test for parametric and non-parametric variables was calculated to determine gender differences. The Chi-square was used to calculate the differences between the categorical variables of physical activity, body composition and handgrip strength. An analysis of variance (ANOVA) was used to determine significant difference between BMI, WC, PA and age groups for all the variables. In order to determine correlations between physical activity, body composition and handgrip strength among the participants, Spearman correlation coefficients (*r*) were employed for the total group and for men and women separately. The level of significance was set at $p \leq 0.05$.

4.4 Results

Maximum handgrip strength was observed in middle life (40-49 years) and in the age group (50-59 years) with a decrease in the 60-70-year group in both the men and women (Table 2). The handgrip strength performance of the underweight men and women was very low with a significant increase ($p<0.05$) in performance in both the normal and overweight group while a decrease in handgrip strength was observed in the obese group. WC significantly differed in the three categories. In terms of physical activity, both the men and women who participated in MVPA for 150 minutes or more per week showed a significant ($p=0.002$) high handgrip strength mean compared to the other two groups. The mean values of the men were high compared to the women across the different physical activity levels.

Table 2: Mean handgrip strength in men and women in the different age groups, physical activity levels and body composition

	Handgrip strength (kg)			
	Men		Women	
Variable	N	Mean ± SD	N	Mean ± SD
Age group				
40-49 years	34	34.81±11.13	88	26.29±7.72
50-59 years	88	34.05±9.20	235	25.12±6.67
60-70 years	76	30.28±8.69	167	23.28±6.45
		p<0.0001		p<0.0001
Underweight	57	30.22±8.81	40	20.8550±5.62
Normal	100	32.89±8.68	161	23.9820±5.95
Overweight	25	36.41±11.37	128	25.8859±7.68
Obese	16	34.96±12.05	161	25.4375±6.96
		p=0.03		p<0.0001
WC risk category very low WC<70 cm (<28.5) in women and <80 cm in men	108	31.46(8.06)	136	22.42±5.86
WC risk category low WC 70-89 cm in women and 80-99 cm in men	73	34.58(10.40)	180	24.54±6.91
WC risk category high 90-109 cm in women and 100-120 cm in men	17	32.88(12.99)	138	26.63±6.87
WC risk category very high >110 cm women and >120 cm in men	-	-	36	26.75±7.67
		p =0.096		p<0.001
Inactive: less than 30 minutes/week of MVPA	33	28.35±9.73	54	22.64±7.84
Insufficiently active: 30-149 minutes/week of MVPA	33	31.16±8.87	134	23.64±6.48
Sufficiently active: 150 minutes/week or more of MVPA	132	34.22±9.53	302	25.54±6.87
		p=0.003		p=0.002

Characteristics according to age groups

Variables	Age groups	N	Mean	SD	Minimum	Maximum	P-value of differences between the groups
Age (year)	42-49 years	122	47.45	1.67	42.49	49.99	<.001
	50-59 years	323	55.03	2.91	50.01	59.96	
	60-70 years	243	64.96	3.02	60.00	70.99	
	Total	688	57.19	6.93	42.49	70.99	
Body weight (kg)	42-49 years	122	63.25	16.15	30.60	109.90	.43
	50-59 years	323	63.73	16.73	32.50	106.50	
	60-70 years	243	65.25	15.84	33.70	105.80	
	Total	688	64.19	16.31	30.60	109.90	
Height (cm)	42-49 years	122	159.14	8.32	143.20	177.10	.95
	50-59 years	323	159.40	11.64	15.00	185.80	
	60-70 years	243	159.17	7.39	140.70	179.10	
	Total	688	159.27	9.75	15.00	185.80	
BMI (kg/m^2)	42-49 years	122	25.02	6.32	14.53	37.79	.33
	50-59 years	323	25.03	6.66	11.47	39.86	
	60-70 years	243	25.80	6.28	14.81	39.93	
	Total	688	25.30	6.47	11.47	39.93	
WC (cm)	42-49 years	122	85.89	14.18	55.30	122.80	.13
	50-59 years	323	86.33	14.84	55.20	122.60	
	60-70 years	243	88.49	13.424	59.10	116.60	
	Total	688	87.01	14.26	55.20	122.80	
Vigmin/wk	42-49 years	122	88.03	226.10	0	1800	.002
	50-59 years	323	62.12	129.37	0	900	
	60-70 years	243	34.96	94.02	0	900	
	Total	688	57.12	142.54	0	1800	
Modmin/wk	42-49 years	122	295.16	275.85	0	1260	.03
	50-59 years	323	322.37	321.08	0	1260	

	60-70 years	243	255.19	265.71	0	1260	
	Total	688	293.82	295.81	0	1260	
Walkmin/wk	42-49 years	122	253.93	247.42	20	1680	.02
	50-59 years	323	282.32	290.23	0	3360	
	60-70 years	243	220.82	224.78	0	1680	
	Total	688	255.57	262.35	0	3360	
MVPA (min/wk)	42-49 years	122	383.19	433.49	.00	2700.00	.007
	50-59 years	323	384.49	392.62	.00	1860.00	
	60-70 years	243	290.14	304.95	.00	1800.00	
	Total	688	350.94	374.34	.00	2700.00	
HGS (kg)	42-49 years	122	28.66	9.56	6.00	66.20	.001
	50-59 years	323	27.55	8.43	9.10	61.90	
	60-70 years	243	25.46	7.91	5.77	48.50	
	Total	688	27.01	8.54	5.77	66.20	

* p-value of the differences; BMI = body mass index; WC = waist circumference; Vigmin/wk = vigorous intensity exercise in minutes per week; Modmin/wk = moderate intensity exercise in minutes per week; walkmin/wk = walking in minutes per week; WHtR = waist to hip ratio; MVPA = moderate to vigorous physical activity per week; HGS= handgrip strength

The results showed that there is a significantly higher (p<0.001) number of participants older than 50 years compared to the number younger than 50 years (Table 3). Out of the 688 participants, 18% of the women and 17% of the men are between the ages of 42-49 years. Forty-eight percent (48%) of the women and 44% of the men are between the ages of 50-59 years and 34% of the women and 38% of the men are between the ages of 60-70 years. The results showed that 29% of the men and women are underweight; 22% are overweight; and 26% are obese. In terms of gender, the results showed that the women are significantly (p<0.001) more overweight (33%) and obese (26%) compared to the men. The WC of women (p=0.001) were found to fall under the higher risk category (90-109cm) with 28% compared to that of the men (8%). The percentage of women who classified under the very high WC risk (>110cm) are 5% higher compared to that of the men. The men were not reported as falling in the very high WC risk category (>120). The men significantly (P=0.001) reported more physical activity than the women while more of the women (27%) categorised with insufficient active levels of 30-149 min/week of MVPA then the men (17%). The men reported with 17%, which is less than 30 min/week of MVPA then women (11%). The result showed the same percentage (17%) for men who are inactive and who classified under an insufficient level of MVP while the percentage of women with regard to the physical activity categories vary.

Table 3: The percentage (%) scores of the participants with regard to body composition and physical activity categories for the total group, men, women, and per age group

Variables		Total group Freq (%)	Men Freq (%)	Women Freq (%)	P-value of the differences
Age groups	42-49 years	122(18)	34(17)	88(18)	<0.001
	50-59 years	323(47)	88(44)	235(48)	
	60-70 years	243(35)	76(38)	167(34)	
	Total	688(100)	198(100)	490(100)	
BMI categories	Underweight	97(14)	57(29)	40(8)	<0.001
	Normal	261(38)	100(50)	161(33)	
	Overweight	153(22)	25(13)	128(26)	
	Obese	177(26)	16(8)	161(33)	
	Total	688(100)	198(100)	490(100)	
WC Categories	WC risk category very low if WC is <70 cm (<28.5) in women and <80 cm in men	244(36)	108(55)	136(28)	<0.001
	WC risk category low 70-89 (28.5-35.0) in women and 80-99 cm in men	253(37)	73(37)	180(37)	
	WC risk category high 90-109 cm (35.5-43.0in) in women and 100-120 cm in men	155(22)	17(9)	138(28)	
	WC risk category very high if WC is >110()>43.5) women and >120 cm in men	36(5)		36(7)	
	Total	688(100)	198(100)	490(100)	
PA Categories	Inactive: less than 30 minutes/week of MVPA	87(13)	33(17)	54(11)	<0.001
	Insufficiently active: 30-149 min/week of MVPA	167(24)	33(17)	134(27)	
	Sufficiently active: 150 min/week or more of MVPA	434(63)	132(66)	302(62)	
	Total	688(100)	198	490(100)	

Body composition and physical activity according to age groups

		Age 42-49	**50-59**	**60-70**	**P-value of the differences**
BMI categories	Underweight	19(16)	55(17)	23(9)	<0.001
	Normal	50(41)	117(36)	94(39)	
	Overweight	19(16)	70(22)	64(26)	
	Obese	34(28)	81(25)	62(26)	
	Total	122(100)	323(100)	243(100)	
WC categories	WC risk category very low <70 cm in women and <80cm in men	46(38)	124(38)	74(30)	<0.001
	WC risk category low 70-89 in women and 80-99 cm in men	47(39)	116(36)	90(37)	
	WC risk category high 90-109 cm in women and 100-120 cm in men	25(20)	63(20)	67(28)	
	WC risk category very high >110 cm women and >120 cm in men	4(3)	20(6)	12(5)	
	Total	122(100)	323(100)	243(100)	
PA categories	Inactive: less than 30 minutes/week of MVPA	10(8)	38(12)	39(16)	<0.001
	Insufficiently active: 30-149 minutes/week of MVPA	30(25)	74(23)	63(26)	
	Sufficiently active: 150 minutes/week or more MVPA	82(67)	211(65)	141(58)	
	Total	122(100)	323(100)	243(100)	

Freq = frequency; BMI = body mass index; WC = waist circumference; PA = physical activity; MVPA = moderate-vigorous physical

Underweight was significantly high in the age groups 42-49 years and 50-59 years, respectively, while overweight and obesity significantly ($p<0.001$) varied in all the age groups (Table 3). In the WC categories, the results showed that both the 42-49 and 50-59 age groups had significantly ($p<0.001$) the same percentage (20%) of a high WC risk categories 90-109 cm in women and 100-120 cm in men. The risk of being associated with a very high WC risk category was lower in all three different age groups 42-49(3%); 50-59(6%); and 60-70(5%).

The mean ages were significantly ($p<0.001$) different with regard to each of the age groups (age group 42-49; mean: 47.46±1.67; age group 50-59, mean: 55.04±3.91; and age group 60-70, mean: 64.96±3.02) (Table 4). The middle-age group significantly performed better in vigorous ($p=0.002$) and moderate activities ($p=0.03$) and walk more minutes per week ($p=0.03$) compared to the 60-70 year old group. In terms of a total MVPA, the middle-age groups performed significantly ($p=0.007$) better than the age group 60-70 years. No significant relationship ($p=0.95$) was reported between the three age groups, as height was found to be the same in all three of the age groups. The mean for handgrip strength significantly ($p<0.001$) decreases with increased age in all three of the age groups. The 42-49 years mean: 28.67±9.56; the 50-59 years mean: 27.55±8.43; and the 60-70 years mean: 25.47±7.9.

Table 4: Mean, standard deviation (±SD) and p- value of the differences with regard to body composition, physical activity and handgrip strength for men and women, according to the age groups

		Age group 42-49			Age group 50-59			Age group 60-70		
Variables		N	Mean±SD	P-value of gender differences	N	Mean±SD	P-value of gender differences	N	Mean±SD	P-value of gender differences
Age (year)	Men	34	47.42(1.76)	.88	88	55.18(2.92)	.58	76	64.91(3.00)	.94
	Women	88	47.47(1.65)		235	54.98(2.92)		167	64.98(3.04)	
Body weight (kg)	Men	34	61.55(13.99)	.47	88	57.44(12.29)	<0.001	76	60.51(14.72)	<0.001
	Women	88	63.91(16.94)		235	66.09(17.57)		167	67.42(15.90)	
Height (cm)	Men	34	167.21(5.48)	<.001	88	167.37(8.12)	<0.001	76	164.97(6.51)	<0.001
	Women	88	156.02(7.05)		235	156.42(11.37)		167	156.53(6.18)	
BMI (kg/m^2)	Men	34	22.03(4.99)	.001	88	20.48(4.22)	<0.001	76	22.16(5.14)	<0.001
	Women	88	26.18(6.42)		235	26.74(6.62)		167	27.46(6.06)	
WC (cm)	Men	34	81.37(13.06)	.03	88	78.69(10.67)	<0.001	76	83.20(12.96)	<0.001
	Women	88	87.63(14.28)		235	89.19(15.18)		167	90.89(12.97)	
Vigmin/wk	Men	34	180.74(328.69)	.002	88	101.82(154.87)	<0.001	76	49.87(122.57)	0.04
	Women	88	52.22(144.42)		235	47.26(115.33)		167	28.17(77.15)	
Modmin/wk	Men	34	382.06(328.49)	.01	88	437.39(386.53)	0.02	76	307.17(300.06)	0.13
	Women	88	261.59(246.60)		235	279.30(281.91)		167	231.53(245.85)	
Walkmin/wk	Men	34	346.47(366.69)	.61	88	327.50(270.66)	0.06	76	239.14(256.21)	0.69
	Women	88	218.18(171.76)		235	265.40(296.01)		167	212.49(209.24)	
MVPA	Men	34	562.79(592.28)	.07	88	539.20(476.11)	<0.005	76	357.04(363.80)	0.10
(min/week)	Women	88	313.80(322.90)		235	326.55(339.81)		167	259.70(269.80)	
HGS (kg)	Men	34	34.81(11.13)	<.001	88	34.05(9.20)	<0.001	76	30.28(8.69)	<0.001
	Women	88	26.29(7.72)		235	25.12(6.67)		167	23.27(6.45)	

BMI = body mass index; WC = waist circumference; Vigmin/wk = vigorous intensity exercise in minutes per week; Modmin/wk = moderate intensity exercise in minutes per week; walkmin/wk = walking in minutes per week; WHtR = waist to hip ratio; MVPA = moderate to vigorous physical activity per week; HGS = handgrip strength.

No significant ($p=0.28$) BMI was found for the women in the three age groups (25 kg/m^2) while the men's BMI was in the region of 22 kg/m^2 (Table 5). Significant differences ($p<0.05$) were found in the handgrip strength of both the men and women. The 60-70 years' group performed poorer than the middle-age group. The men in the middle-age group significantly participated in vigorous activities per week compared to the 60-70 years' group. A similar trend, though not significant ($p>0.05$), was found in the women.

Table 5: The descriptive characteristics (mean, SD, minimum, maximum and p-value of the differences between the groups) of the men and women

		Men					Women				
Variables		N	Mean	SD	*F*	P-value of the differences between groups	N	Mean	SD	F	P-value of the differences between groups
Weight (kg)	42-49 years	34	61.55	13.99			88	63.91	16.94	1.241	.29
	50 to 59 years	88	57.44	12.29	1.597	.20	235	66.09	17.56		
	60 to 70 years	76	60.51	14.73			167	67.42	15.90		
Height (cm)	42-49 years	34	167.21	5.48	2.567	.08	88	156.02	7.05	.091	.913
	50 to 59 years	88	167.37	8.12			235	156.42	11.37		
	60 to 70 years	76	164.97	6.51			167	156.53	6.18		
BMI (kg/m^2)	42-49 years	34	22.03	4.99	2.932	.06	88	26.18	6.43	1.268	.28
	50 to 59 years	88	20.48	4.23			235	26.74	6.61		
	60 to 70 years	76	22.16	5.14			167	27.46	6.06		
WC (cm)	42-49 years	34	81.37	13.06	2.907	.06	88	87.63	14.28	1.602	.20
	50 to 59 years	88	78.69	10.67			235	89.19	15.18		
	60 to 70 years	76	83.20	12.96			167	90.89	12.97		
HGS (kg)	42-49 years	34	34.81	11.13	4.308	.01	88	26.29	7.72	6.528	.002
	50 to 59 years	88	34.05	9.20			235	25.12	6.67		
	60 to 70 years	76	30.28	8.69			167	23.27	6.45		
Vigmin/wk	42-49 years	34	180.74	346.69	5.551	.01	88	52.22	144.42	1.957	.14
	50 to 59 years	88	101.82	154.87			235	47.26	115.33		
	60 to 70 years	76	49.87	122.57			167	28.17	77.15		
Modmin/wk	42-49 years	34	382.06	328.49	2.895	.06	88	261.59	246.60	1.602	.20
	50 to 59 years	88	437.39	386.53			235	279.30	281.91		
	60 to 70 years	76	307.17	300.06			167	231.53	245.85		
Walkmin/wk	42-49 years	34	346.47	366.68	2.599	.08	88	218.18	171.76	2.563	.08
	50 to 59 years	88	327.50	270.66			235	265.40	296.01		
	60 to 70 years	76	239.14	256.20			167	212.49	209.24		
Sitmin/wk	42-49 years	34	235.29	128.52	5.007	.01	88	275.68	144.78	1.449	.24
	50 to 59 years	88	275.68	179.51			235	263.66	126.58		
	60 to 70 years	76	337.63	175.79			167	286.77	140.09		
MVPA/wk	42-49 years	34	562.79	592.28	3.978	.02	88	313.80	332.90	2.261	.11
	50 to 59 years	88	539.20	476.11			235	326.55	339.81		
	60 to 70 years	76	357.04	363.80			167	259.70	269.80		
	Total	198	473.33	466.69			490	301.48	317.19		

BMI = body mass index; WC = waist circumference; Subs = subscapular skinfold; Vigmin/wk = vigorous intensity exercise in minutes per week; Modmin/wk = moderate intensity exercise in minutes per week; walkmin/wk = walking in minutes per week; WHtR = waist to hip ratio; MVPA = moderate to vigorous physical activity per week.

A negative correlation was found between height and waist, BMI and age. However, a positive correlation was found between body mass and MVPA. BMI related positively with body mass, waist and age but a negative correlation was found with MVPA (6). Handgrip strength positively correlated related with body mass, height and MVPA while an inversely correlation was found with age. MVPA negatively (r= -0.12; p=0.001) correlated with age.

When the data were analysed separately, the measurements of the men differed significantly with regard to body composition, such as body mass, waist and BMI, compared to the measurements of the women. A positive correlation was found between body mass, waist and BMI. A negative relationship was found between BMI and height (r= -0.6; p= 0.37). A positive relationship was found between all of the anthropometric measures of body composition. However, an inversely relation was found with age (r= -0.23; p=0.001). A negative correlation was found between MVPA (r= -0.19; p=0.006) and age.

A positive correlation was found between four of the five body composition measurements that were significant (p=0.000). Handgrip strength correlated positively with the five body composition measurements while a negative correlation was found between handgrip strength (r= -0.18; p=0.000) and age. MVPA also negatively correlated with age (r= -0.11; p=0.01).

Table 6: Correlation coefficients (r) between body composition, physical activity and handgrip strength of the total group

TOTAL GROUP

		Weight	Height	BMI	Waist	WHtR	MVPA	Age
Weight (cm)	r	-	.16**	.92**	.90**	.81**	-.02	.04
	p	.	.00	.00	.00	.00	.63	.33
Height (cm)	r	.16**	-	-.20**	-.02	-.29**	.06	-.004
	p	.00	.	.00	.58	.00	.12	.92
BMI (kg/m²)	r	.92**	-.20**	-	.91**	.92**	-.04	.04
	p	.00	.00	.	.00	.00	.35	.28
Waist (cm)	r	.90**	-.02	.91**	-	.95**	-.07	.06
	p	.00	.58	.00	.	.00	.08	.09
HGS (kg)	r	.16**	.44**	-.01	.06	-.06	.25**	-.15**
	p	.00	.00	.82	.09	.12	<.001	<.001
MVPA	r	-.02	.06	-.04	-.07	-.07	-	-.123**
(min/wk)	p	.63	.12	.35	.08	.06	.	.001
Age (year)	r	.04	-.004	.04	.06	.06	-.12**	-
	p	.33	.92	.28	.09	.10	.001	.

MEN

		Weight	Height	BMI	Waist	HGS	WHtR	MVPA	Age
Weight (kg)	R	-	.28**	.92**	.90**	.278**	.79**	-.03	.03
	P	.	.000	.000	.000	.000	.000	.61	.62
Height (cm)	R	.28**	-	-.06	.11	.184**	-.17*	-.14	-.13
	P	.000	.	.37	.11	.009	.02	.05	.07
BMI (kg/m²)	R	.92**	-.06	-	.89**	.240**	.90**	.008	.07
	P	.000	.37	.	.000	.001	.000	.91	.32
WC (cm)	R	.90**	.11	.89**	-	.195**	.95**	-.07	.12
	P	.000	.11	.000	.	.006	.000	.29	.08
HGS (kg)	R	.28**	.18**	.24**	.19**	-	.15*	.24**	-.23**
	P	.000	.01	.001	.01	.	.04	.001	.001
MVPA	R	-.03	-.14	.01	-.07	.243**	-.04	-	-.19**
(min/wk)	P	.61	.05	.91	.29	.001	.57	.	.006
Age (year)	R	.03	-.13	.07	.12	-.233**	.16*	-.19**	-
	P	.62	.07	.32	.08	.001	.02	.006	.

WOMEN

		Weight	Height	BMI	Waist	Triceps	HGS	WHtR	MVPA	Age
Weight (kg)	R	-	.34**	.95**	.90**	.76**	.28**	.82**	.03	.04
	P	.	.000	.000	.000	.000	.000	.000	.43	.33
Height (cm)	R	.34**	-	.05	.19**	.13**	.35**	-.06	.03	.01
	P	.000	.	.27	.000	.005	.000	.16	.49	.80
BMI (kg/m²)	R	.95**	.05	-	.89**	.77**	.18**	.89**	.03	.05
	P	.000	.27	.	.000	.000	.000	.000	.51	.29
WC (cm)	R	.90**	.19**	.89**	-	.72**	.23**	.96**	-.008	.06
	P	.000	.000	.000	.	.000	.000	.000	.86	.18
HGS (kg)	R	.28**	.35**	.18**	.23**	.22**	-	.14**	.18**	-.18**
	P	.000	.000	.000	.000	.000	.	.002	.000	.000
MVPA	R	.03	.03	.03	-.008	-.05	.18**	-.01	-	-.11*
(min/wk)	P	.43	.49	.51	.86	.25	.000	.75	.	.01
Age (year)	R	.04	.01	.05	.06	-.007	-.18**	.06	-.11*	-
	P	.33	.80	.29	.18	.87	.000	.15	.01	.

** A correlation is significant at the 0.01 level (2-tailed); * A correlation is significant at the 0.05 level (2-tailed); BMI = body mass index; WC = waist circumference; WHtR = waist to hip ratio; MVPA = moderate to vigorous physical activity per week; HGS = handgrip strength

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4.4.1 Discussion

The purpose of this study was to determine a correlation between physical activity, body composition and handgrip strength among adults from the North West, South Africa. A positive correlation was found between handgrip strength and MVPA, but both handgrip strength and MVP were negatively related with age. The results of the study are congruent with the findings of Smith et al.[36] who found that maximum strength is observed in middle life (40-49 years) and between the ages of 50-59 years. A decrease took place in the handgrip strength in both the men and the women between the ages of 60-70 years resulting in poor handgrip strength performance compared to the participants in the middle-age group.

Overweight and obesity were 22% and 26%, respectively. The women are more overweight (26%) and obese (33%) compared to the men (13% overweight and 8% obese). The findings of this study are similar to previous studies[37,38,39,40,41,42] with the prevalence of overweight and obesity consistently high in most countries (i.e., The United States of America, Spain, United Kingdom, Mexico, Australia and Ghana) exceeding 30% in the elderly age group for both men and women. A survey conducted by Kruger et al.[43] in transitional African communities in the North West, South Africa, also reported that inactivity – independent of the degree of urbanisation – is significantly (p= 0.0007) associated with high obesity levels that is similar to the findings of this study.

Furthermore, the study reported a negative correlation between age and MVPA, but a significant decline in physical activity with increased age, especially in the elderly in the age group 60-70 years, was found. This negative correlation in the study between MVPA and age can be due to the fact that the selected average age group of the population was mostly individuals who were prone to physical inactivity, a sedentary lifestyle and more disposed to functional limitations that hindered them from being physically active. Furthermore, the age group individuals of our study have been reported by other studies to suffer from health problems (non-communicable diseases, such as high blood pressure) which limit them from being physically activity compared to other age groups (i.e. children and adolescents).[2,44,10] Other studies[44,45] have reported a similar decline in MVPA with increased age, resulting in functional limitations that can serve as an indicator of their health status and a predictor of future events, such as disabilities.

The study also reported a negative correlation between age and handgrip strength. However, a poor handgrip strength performance was constantly associated with increased age (elderly individuals around the age of 60 years). The negative correlation can, therefore be due to function limitations, poor or weak strength and endurance of muscles that is associated with old age, as the target age group was found to be associated with disadvantages of advancing age. Robert et al. reported that [46], the precision of handgrip strength measurements can be influenced by protocol, such as allowance for hand size, hand dominance, posture, joint position, effort and encouragement, frequency of testing and time of the day – regardless of age. An explanation for the negative correlation between handgrip strength and age can be due to factors, such as hand size, joint posture and time of the measurements that can influence a correlation between handgrip strength and age. Moreover, the findings of the study found no correlation between handgrip strength and anthropometric measurements, such as BMI and waist circumference for the total group measured. However, when the data were further analysed according to gender, a positive correlation between handgrip strength and all of the anthropometric measurements was noted for both the men and women. These results are similar to findings that were reported in[26] a study where a lower handgrip strength was associated with being overweight, a high body fat and high BMI values while a high handgrip strength is associated with individuals who have a normal BMI value.

An association between physical activity and handgrip strength was noted in this study in both the men and women, illustrating that physical activity and handgrip strength significantly decrease with age. These findings are consistent with other studies.[1,47,33] When it comes to body composition, the BMI consistently increased with age and the women consistently reported high BMI values, poor physical activity performance compared to the values of the men. These findings may imply that improved physical activity can benefit individuals with weak muscles and physical activity can be used to influence quality of life.[45,48] Other studies[27,30,4950] explained the importance of physical activity in muscle strength and BMI based on their role in supporting muscle mass by decelerating the progression of function limitations and disability in older adults. Physical activity remains, therefore, a key element in preventing and/or treating non-communicable diseases and disabilities compromised by poor muscle strength.[50,2,51]

The study had several strengths and limitations that should be taken into consideration when the results of the study are interpreted. The study utilised a large sample and included data from both urban and rural areas in the North West. In spite of these strengths, given the cross-sectional nature of the study, causal relationships could not be determined. Additionally, the bias and recall problems linked to the use of the questionnaire in assessing physical activity. Future studies should, therefore incorporate objective measures of physical activity. Other study limitations of the study were that fat free mass was not measured and the socioeconomic status of the participants was not considered. The socioeconomic status of the participants can influence physical activity participation, body composition and muscles strength. The findings of the study are limited to the North West and cannot, therefore be generalised.

4.4.2 Conclusion

A high BMI is associated with less MVPA per week with women more affected than men. Furthermore, the results showed that aging significantly affects functional performance with regard to handgrip strength and MVPA in both men and women. As such, the study recommends an urgent strategic physical intervention in older men and women to improve their quality of life.

4.4.3 Acknowledgements

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Competing interests

The authors declare that there are no competing interests.

4.4.4 Authors' contributions

SS, an MA student (North-West University), was responsible for the development of the objectives, data collection, data arrangements, interpretation and write-up of the article. SJM commented on the design, the write-up and the final article. MAM contributed to the data analyses, write-up, and commented on the final articles and dissertation. CP contributed to the write-up of the dissertation.

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CHAPTER 5
SUMMARY, CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

5.1 Summary

There was a consistent and progressive trend with regard to a decrease in physical activity with increasing age in the elderly group of people between the ages of 40-60 years (Hall *et al.,* 2017:575). A correlation was found between a decrease in physical activity with age and health risk factors, such as functional limitations, poor muscle strength performance (handgrip strength), and non-communicable diseases (World Health Organization, 2016:10; Lee *et al.,* 2012:227; Lenard *et al.,* 2016:90; Hall *et al.,* 2017:575). A high level of obesity that impacts the quality of life of adults was reported in Sub-Saharan Africa (Walker *et al.,* 2001:368). The individuals in the 40-60 years group were categorised in the high BMI category and they also showed low levels of physical activity. The study highlights the importance of physical activity in the elderly age groups as an important element necessary for growth and to maintain good health – physical activity has a positive impact on their overall health (Stewart *et al.,* 2007:17; Sternäng *et al.,* 2015:270). In order to understand the underlying reasons for a decrease in physical activity, muscle strength, an increase in BMI levels and the relationships between variables (physical activity, handgrip strength and body composition) among adults were studied. The main purpose of this study was, therefore, to determine and explore the relationships between physical activity, body composition and handgrip strength among South African adults living in North West.

The dissertation is presented in article format according to the guidelines of the North-West University and was approved by the research committee. Chapters 3 and 4 are presented in the form of independent research articles that will be submitted to accredited peer-reviewed journals for publication. Chapter 1 provided an overview of the problem statement, the objectives and hypotheses of the study as well as the structure of the dissertation.

Chapter 2 presented a literature review that discussed the physical activity levels among adults. It shared insight in terms of how physical inactivity has a positive association with the manifestations of non-communicable diseases among adults. In addition, poor functional capacity, such as a poor handgrip in adults, was found to be associated with various health issues, such as physical and functional limitations together with poor handgrip strength and may prevent individuals from performing daily activities that require muscle strength (Germain *et al.,* 2016). In addition, the literature review revealed that inactivity has a significant link with non-communicable diseases, such as coronary heart disease, Type 2 diabetes, and breast and colon cancers. Non-communicable diseases are, therefore, the biggest contributor to deaths in African regions. Physical activity is viewed as an important element contributing to the health of the elderly. In a report on 22 African countries – including South Africa – physical activity trends showed that approximately 84% of men and 76% of women in the sample were in line with the physical activity recommendations provided by the World Health Organization (Guthold *et al*., 2011). A decrease in handgrip strength and physical inactivity in the elderly have significant implications for public health and physical interventions are urgently needed to promote a healthy lifestyle.

5.2 Conclusions

The conclusions of the study are in accordance with the objectives and hypotheses stated in Chapter 1.

5.2.1 Hypothesis 1:

Significant differences will exist in a comparison of physical activity and handgrip strength in relation to body mass index (BMI) between male and female young and middle adults in the North West, South Africa.

The results showed that 29% of the men and 22% of the women were underweight while 22% of the men and 26% of the women were overweight and/or obese. The men were more physically active, taller and underweight compared to the women in all of the age groups while the woman showed high mean values for triceps, subscapular and waist circumference compared to the men. Regardless of age and gender, the underweight and normal weight groups reported higher physical activity levels and handgrip strength compared to the overweight and obese groups. Handgrip strength according to the age groups was significantly ($p<0.05$) better in the men (42-49 years; men 34.81 ± 11.13 kg versus women 26.29 ± 7.72 kg; 50-59 years; men 34.05 ± 9.19 kg versus women 25.12 ± 6.67 kg; 60-70 years; men 30.28 ± 8.69 kg versus women 23.27 ± 6.44 kg) compared to the women ($p<0.05$). The overweight and obese men performed poor in MVPA minutes per week compared to the men in the other BMI categories. Based on these results, hypothesis 1 can, therefore, be *accepted.*

5.2.2 Hypothesis 2:

There will be a significant positive correlation between high levels of physical activity, low body composition and greater handgrip strength among young and middle adults in the North West, South Africa.

Overweight was reported in 22% and obesity in 26% of the total group of participants. The women were significantly ($p<0.001$) more overweight (26%) and obese (33%) compared to the men (13% overweight and 8% obese). Sixty percent (60%) of the participants reported sufficient physical activity per week. Seventeen percent (17%) of the men and 27% of the women were physically inactive per week. Handgrip strength performance significantly ($p<0.05$) differed according to age. In general, the handgrip strength of the participants was poor when compared to available handgrip strength norms. The participants aged younger than 50 years outperformed the older groups with the men stronger than the women. The men and women who were sufficiently active per week significantly ($p<0.05$) performed better than the other groups. A positive correlation was found between handgrip strength and BMI. A negative correlation was found between MVPA ($r= -0.12$; $p=0.001$) and age. A negative correlation was found in both the men ($r= -0.23$; $p= 0.001$) and women ($r= -0.18$; $p=0.000$) between handgrip strength xxx and age. The hypothesis can, therefore, be *partially accepted*.

The literature review highlighted the negative effects with regard to aging and obesity on functional performance and the physical activity of elderly people. Findings from the two articles were intertwined with the findings discussed in the dissertation to demonstrate the co-existence of underweight and obesity with women more obese than men. The co-existence of underweight and obesity in the study may be attributed to a nutritional transition and a poor socioeconomic status. What was encouraging in the study regardless of the existence of underweight and obesity was that 60% of the participants reported sufficient physical activity per week. The observed participation in physical activity may be explained by the fact that the participants in the study are mostly from rural or poor settings where walking is the mode of transport.

In addition, the results showed that the men performed better than the women in handgrip strength. The observed differences between the men and women in terms of handgrip strength may be explained by the physiological underpinning that men have more muscle mass and higher levels of testosterone on average, which mean they use more energy than women do. The underweight and normal men and women in the study participated more in physical activity compared to the overweight and obese men and women. The low participation in physical activity by both the overweight and obese groups proves that the physical nature of the overweight or obese individuals affected their participation in physical activity. It was also evident from the results that the men and women who were older than 50 years in the study performed poorly in handgrip strength. The reduction in strength performance with age is not strange, since it was clear in the literature that when people age, they tend to loss muscle strength, which in turn can be associated with poor functional performance. The biggest concern from these findings is that if strategic physical activity interventions (incorporating strength activities and body composition measurements) are not implemented, the adult population in these areas may be faced with a bleak future and they will be susceptible to chronic diseases due to a sedentary lifestyle.

5.3 Limitations and recommendations

The present study has several limitations that should be noted when the results are interpreted and these limitations should be addressed in future research. The cross-sectional nature of the research design can be viewed as a limitation of the study, since no causal relationships were determined. Future researchers should make use of a longitudinal study design so that comprehensive results with regard to physical activity, body mass index and handgrip strength of elderly people can be understood. The sample was based in the North West of South Africa; the selection of participants did not include a diversity of South Africans from all of the nine provinces and can limit the generalisability of the findings. Moreover, the inclusion of only black participants in the study can be viewed as a limitation when findings are compared. Future researchers should include a more balanced set of participants based on gender, race, culture and socioeconomic status.

This study made use of a self-reported international physical activity questionnaire-short form to obtain information on the physical activity status and participation in physical activity. However, self-reported measurements lack an introspective ability to provide accurate responses to questions. Self-report methods are, therefore, often fraught with issues of recall and response bias. The use of objective measures concerning physical activity (ActiHeart and ActiGraph) in future studies can minimise bias when participants have to respond with regard to their level of physical activity participation.

The study did not focus on dietary intake/nutritional status data, lifestyle information or metabolic risk factors while other factors, such as culture and the environment, were also not taken into account. The possible effect of these factors on physical activity, handgrip strength and body mass index was not investigated or assessed as predictors of mortality and undernourishment.

The findings of the study support the call that elderly people should engage in physical activity for overall health – not only for muscle strength and body composition alone but other aspects, such as physical activity, also play a role in the health and quality of life of individuals. If non-communicable disease risk factors can be reduced, life can be prolonged. The findings of the study highlight the importance of physical activity programmes aimed at reducing risks associated with an inactive lifestyle that threatens the quality of life of the elderly. These physical activity programmes must be implemented to improve their lives.

5.4 Future research

From the findings and limitations of this study, a specific need for additional research is evident with regard to the physical activity, body composition, handgrip strength, nutritional status, and metabolic risks factors among South African young and middle adults living in the North West, South Africa. In addition, interventions focusing on physical activity to develop functional capacity and the body composition of adults in the North West are of the utmost importance. In addition, the role of physical activity and body composition on metabolic risk factors can also be researched.

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APPENDIXES

APPENDIXE: A

DATA CARD

PARTICIPANT ID:			
DoB:			
Age:			
Sex	Man	Women	
ANTHROPOMETRIC MEASUREMENTS			
	Trial 1	Trial 2	Average
Stature (cm)			
Body mass (kg)			
Girth			
Waist circumfence (cm)			
HAND GRIP (kg)			
	Trial 1	Triral 2	Average
Dominant hand (kg)			
Non-dominant hand (kg)			

APPENDIXE: B

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRES

IPAQ: SHORT LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health-related physical activity.

Background on IPAQ

The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken in 12 countries (14 sites) across 6 continents during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages. IPAQ is suitable for use in regional, national and international monitoring and surveillance systems and for use in research projects and public health program planning and evaluation. International collaboration on IPAQ is on-going and an international prevalence study is under development.

Using IPAQ

Worldwide use of the IPAQ instruments for monitoring and research purposes is encouraged.

It is strongly recommended, to ensure data quality and comparability and to facilitate the development of an international database on health-related physical activity, that

- no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments,
- if additional questions on physical activity are needed they should follow the IPAQ items,
- translations are undertaken using the prescribed back translation methods (see website)
- new translated versions of IPAQ be made available to others via the web site to avoid duplication of effort and different versions in the same language,
- a copy of IPAQ data from representative samples at national, state or regional level be provided to the IPAQ data storage center for future collaborative use (with permission) by those who contribute.

More Information

Two scientific publications presenting the methods and the pooled results from the IPAQ reliability and validity study are due out in 2002.

More detailed information on the IPAQ process, the research methods used in the development of the IPAQ instruments, the use of IPAQ, the published papers and abstracts and the on-going international collaboration is available on the IPAQ web-site.

www.ipaq.ki.se

This is the final SHORT LAST 7 DAYS SELF-ADMINISTERED version of IPAQ from the 2000/01 Reliability and Validity Study. Completed May 2001.

APPENDIXE: C

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

INFORMATION LEAFLET AND WRITTEN INFORMED CONSENT FORM FOR PARTICIPANTS OF THE PURE STUDY

TITLE OF THE RESEARCH PROJECT: Prospective Urban and Rural Epidemiology (PURE) study

REFERENCE NUMBERS: NWU-00016-10-A1

PRINCIPAL INVESTIGATORS: Prof A Kruger and Dr IM Kruger

ADDRESS: North-West University (Potchefstroom Campus), Africa Unit for Transdisciplinary Health Research (AUTHeR), Building E6, Office G03.

APPENDIXE: D

YUNIBESITI YA BOKONE-BOPHIRIMA
NORTH WEST UNIVERSITY
NOORDWES UNIVERSITEIT

POTCHEFSTROOM CAMPUS

PURE-SA Project (Prospective Urban and Rural Epidemiology)
INFORMED CONSENT FORM (including the PRIMER-study)

I, the undersigned ……………………………………………………………………………………(full names)

read / listened to the information on the project in PART 1 and PART 2 of this document and I declare that I understand the information. I had the opportunity to discuss aspects of the project with the project leader and I declare that I participate in the project as a volunteer. I hereby give my consent to be a subject in this project.

I agree to be tested for HIV …………………………	Yes	No
I want to know my HIV-status …………………………	Yes	No
I agree to give a blood sample …………………………	Yes	No

I hereby also declare that I am aware that:

1. this blood sample will be used for the purpose of
   a. Isolating DNA to look at genetic factors that are currently associated with Type 2 Diabetes (i.e. the Calpain10, Adiponectin, Leptin and Leptin Receptor genes), or genetic factors that may be associated with Non Communicable diseases in the future. We give the assurance that all genetic tests and experiments will only focus on genotypes suspected to contribute to an increased risk of non communicable diseases of lifestyle.
   b. Testing for liver function by determining liver enzymes such as AST, GGT,
   c. Analyses of other than genetic parameters for Diabetes Mellitus such as HbA_1C, Blood glucose and Insulin
   d. Analyses of clotting factors and hypertension markers
   e. Analyses of bone health, iron and nutrition status
   f. And may be stored until such time as the above measurements/analyses will be done.
2. A two hour glucose tolerance test will be done
3. Body measurements such as height, weight, skinfold thicknesses, arm and leg circumferences will be taken
4. Electrocardiograph be taken
5. Blood pressure to be taken
6. Pulse wave velocity measurements will be made
7. A urine sample to be collected to analyse for the presence of heavy metals such as lead and mercury.
8. A Spirometer test to be performed to determine lung function
9. A handgrip test to be performed to test muscle strength
10. A hair sample to be taken to test for fumonisin mycotoxins.

………………………………………………………
(Signature of the subject)

Signed at … **Potchefstroom / Ganyesa** … (delete not applicable option) on ………/………/ **2005**

Witnesses

1. ……………………………………………… **2.** ………………………………………………

Signed at … **Potchefstroom / Ganyesa** … (delete not applicable option) on ………/………/ **2005**

Page 1 of 3

APPENDIXE: E

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOMKAMPUS

Permission for the use of PURE-SA data

Dear Chair and members of the HREC

I, Dr IM (Lanthé) Kruger, project leader of the South African arm of the Prospective Urban and Rural Epidemiological (PURE-SA) study, hereby grant the following student / researcher permission to use the following data from the PURE study in order to fulfill the requirements of their intended research.

Date signed 26/06/2017

Signature

Please complete ALL sections below

Student name and surname
Sindisiwe Shozi

Student number
27356844

Proposed title of research project
Physical activity, body composition and handgrip strength among South African young and middle adults: the PURE study

Qualification

- ○ Honours
- ⦿ Masters
- ○ PhD
- ○ Not for qualification purposes

Supervisor / Primary researcher
Prof. Andries Monyeki

Co-supervisor / Secondary researcher
Prof. Hanlie Moss

APPENDIXE: F

JOURNAL GUIDELINES

African Journal of Primary Health Care & Family Medicine (PHCFM)

Original Research Articles

An original article provides an overview of innovative research in a particular field within or related to the focus and scope of the journal, presented according to a clear and well-structured format. Systematic reviews should follow the same basic structure as other original research articles. The aim and objectives should focus on a clinical question that will be addressed in the review. The methods section should describe in detail the search strategy, criteria used to select or reject articles, attempts made to obtain all important and relevant studies and deal with publication bias (including grey and unpublished literature), how the quality of included studies was appraised, the methodology used to extract and/or analyse data. Results should describe the homogeneity of the different findings, clearly present the overall results and any meta-analysis.

Word limit	3500-7000 words (excluding the structured abstract and references)
Structured abstract	250 words to cover a Background, Aim, Setting, Methods, Results and Conclusion
References	60 or less
Tables/Figures	no more than 7 Tables/Figure
Ethical statement	should be included in the manuscript
Compulsory supplementary file	ethical clearance letter/certificate
Language	only manuscripts presented in English or French will be considered

Obituaries

Is a news article that reports the recent passing of a person, typically along with an account of the person's work achievement and life.

Word limit	400 words
Photo	a photograph of the deceased

Review Articles

These must be critical reviews of the literature on topics that have social, economic or scientific values, and must be within the focus and scope of the journal.

Word limit	2500-4000 words (excluding the structured abstract and references)
Structured abstract	250 words to cover a Background, Aim, Method, Results and Conclusion
References	50 or less
Tables/Figures	no more than 4 Tables/Figure
Ethical statement	should be included in the manuscript, if applicable
Language	only manuscripts presented in English or French will be considered

Correspondence

They may be subjected to the peer review process and their eventual placement is at the discretion of the editorial team. Kindly include include a correspondence address.

Word limit	400 words (excluding the references)
Abstract	n/a
References	10 or less
Tables/Figures	no more than 1 Tables/Figure

Patient studies

A detailed account of a specific patient as a case study. The patient study should highlight a critical issue that is relevant to the field of family medicine and primary care.

Word limit	1500 words (excluding the unstructured abstract and references)
Unstructured abstract	75 words to cover a Background, Aim, Method, Results and Conclusion
References	15 or less
Tables/Figures	no more than 6 Tables/Figure
Ethical statement	should be included in the manuscript
Compulsory supplementary file	ethical clearance letter/certificate

Cover Letter

The format of the compulsory cover letter forms part of your submission. It is located on the first page of your manuscript and should always be presented in English. You should provide the following elements:

1. Full title: Specific, descriptive, concise, and comprehensible to readers outside the field, max 95 characters (including spaces).
2. Tweet for the journal Twitter profile: This will be used on the journal Twitter profile to promote your published article. Max 101 characters (including spaces). If you have a Twitter profile, please provide us your Twitter @ name. We will tag you to the Tweet
3. Full author details: The title(s), full name(s), position(s), affiliation(s) and contact details (postal address, email, telephone, highest academic degree, Open Researcher and Contributor Identification (ORCID) and cell phone number) of each author.
4. Corresponding author: Identify to whom all correspondence should be addressed.
5. Authors' contributions: Briefly summarise the nature of the contribution made by each of the authors listed.
6. Disclaimer: A statement that the views expressed in the submitted article are his or her own and not an official position of the institution or funder.
7. Source(s) of support: These include grants, equipment, drugs, and/or other support that facilitated conduct of the work described in the article or the writing of the article itself.
8. Summary: Lastly, a list containing the number of words, pages, tables, figures and/or other supplementary material should accompany the submission.

Anyone that has made a significant contribution to the research and the paper must be listed as an author in your cover letter. Contributions that fall short of meeting the criteria as stipulated in our policy should rather be mentioned in the 'Acknowledgements' section of the manuscript.
Read our **authorship** guidelines and **author contribution** statement policies.

Original Research Article full structure

Title: The article's full title should contain a maximum of 95 characters (including spaces).

Abstract: The abstract, written in English, should be no longer than 250 words and must be written in the past tense. The abstract should give a succinct account of the objectives, methods, results and significance of the matter. The structured abstract for an Original Research article should consist of six paragraphs labelled Background, Aim, Setting, Methods, Results and Conclusion.

- Background: Summarise the social value (importance, relevance) and scientific value (knowledge gap) that your study addresses.
- Aim: State the overall aim of the study.
- Setting: State the setting for the study.
- Methods: Clearly express the basic design of the study, and name or briefly describe the methods used without going into excessive detail.

- Results: State the main findings.
- Conclusion: State your conclusion and any key implications or recommendations.

Do not cite references and do not use abbreviations excessively in the abstract.

Introduction: The introduction must contain your argument for the social and scientific value of the study, as well as the aim and objectives:

- Social value: The first part of the introduction should make a clear and logical argument for the importance or relevance of the study. Your argument should be supported by use of evidence from the literature.
- Scientific value: The second part of the introduction should make a clear and logical argument for the originality of the study. This should include a summary of what is already known about the research question or specific topic, and should clarify the knowledge gap that this study will address. Your argument should be supported by use of evidence from the literature.
- Conceptual framework: In some research articles it will also be important to describe the underlying theoretical basis for the research and how these theories are linked together in a conceptual framework. The theoretical evidence used to construct the conceptual framework should be referenced from the literature.
- Aim and objectives: The introduction should conclude with a clear summary of the aim and objectives of this study.

Research methods and design: This must address the following:

- Study design: An outline of the type of study design.
- Setting: A description of the setting for the study; for example, the type of community from which the participants came or the nature of the health system and services in which the study is conducted.
- Study population and sampling strategy: Describe the study population and any inclusion or exclusion criteria. Describe the intended sample size and your sample size calculation or justification. Describe the sampling strategy used. Describe in practical terms how this was implemented.
- Intervention (if appropriate): If there were intervention and comparison groups, describe the intervention in detail and what happened to the comparison groups.
- Data collection: Define the data collection tools that were used and their validity. Describe in practical terms how data were collected and any key issues involved, e.g. language barriers.
- Data analysis: Describe how data were captured, checked and cleaned. Describe the analysis process, for example, the statistical tests used orsteps followed in qualitative data analysis.
- Ethical considerations: Approval must have been obtained for all studies from the author's institution or other relevant ethics committee and the institution’s name and permit numbers should be stated here.

Results: Present the results of your study in a logical sequence that addresses the aim and objectives of your study. Use tables and figures as required to present your findings. Use quotations as required to establish your interpretation of qualitative data. All units should conform to the SI convention and be abbreviated accordingly. Metric units and their international symbols are used throughout, as is the decimal point (not the decimal comma).

Discussion: The discussion section should address the following four elements:

- Key findings: Summarise the key findings without reiterating details of the results.
- Discussion of key findings: Explain how the key findings relate to previous research or to existing knowledge, practice or policy.
- Strengths and limitations: Describe the strengths and limitations of your methods and what the reader should take into account when interpreting your results.
- Implications or recommendations: State the implications of your study or recommendations for future research (questions that remain unanswered), policy or practice. Make sure that the recommendations flow directly from your findings.

Conclusion: Provide a brief conclusion that summarises the results and their meaning or significance in relation to each objective of the study.

Acknowledgements: Those who contributed to the work but do not meet our authorship criteria should be listed in the Acknowledgments with a description of the contribution. Authors are responsible for ensuring that anyone named in the Acknowledgments agrees to be named.

Also provide the following, each under their own heading:

- Competing interests: This section should list specific competing interests associated with any of the authors. If authors declare that no competing interests exist, the article will include a statement to this effect: *The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.* Read our policy on competing interests.
- Author contributions: All authors must meet the criteria for authorship as outlined in the **authorship** policy and **author contribution** statement policies.
- Funding: Provide information on funding if relevant
- Disclaimer: A statement that the views expressed in the submitted article are his or her own and not an official position of the institution or funder.

References: Authors should provide direct references to original research sources whenever possible. References should not be used by authors, editors, or peer reviewers to promote self-interests. Refer to the journal referencing style downloadable on our *Formatting Requirements* page.

Review Article full structure

Title: The article's full title should contain a maximum of 95 characters (including spaces).

Abstract: The abstract should be no longer than 250 words and must be written in the past tense. The abstract should give a concise account of the objectives, methods, results and significance of the matter. The abstract can be structured and should consist of five paragraphs labelled Background, Aim, Method, Results and Conclusion.

- Background: Why is the topic important to us? State the context of the review

- Aim: What is the purpose of your review ? Describe the aim or purpose of your review.
- Method: How did you go about performing the review? Describe the methods used for searching, selecting and appraising your evidence.
- Results: What are the findings? What are the main findings of your literature review.
- Conclusion: What are the implications of your answer? Briefly summarise any potential implications.

Introduction: Present an argument for the social and scientific value of your review that is itself supported by the literature. Present the aim and objectives of your literature review.

Methods: Although this is not a systematic review (see instructions on original research for this type of article) it is still necessary to outline how you searched for, selected and appraised the literature that you used. Discuss any methodological limitations.

Review findings: Present your review of the literature and make use of appropriate sub-headings. Your review should be a critical synthesis of the literature.

Implications and recommendations: Discuss the findings of your review in terms of the implications for policy makers and clinicians or recommendations for future research.

Conclusion: This should clearly state the main conclusions of the review in terms of addressing the original aim and objectives.

Acknowledgements: Those who contributed to the work but do not meet our authorship criteria should be listed in the Acknowledgments with a description of the contribution. Authors are responsible for ensuring that anyone named in the Acknowledgments agrees to be named.

Also provide the following, each under their own heading:

- Competing interests: This section should list specific competing interests associated with any of the authors. If authors declare that no competing interests exist, the article will include a statement to this effect: *The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.* Read our policy on competing interests.
- Author contributions: All authors must meet the criteria for authorship as outlined in the **authorship** policy and **author contribution** statement policies.
- Funding: Provide information on funding if relevant
- Disclaimer: a statement that the views expressed in the submitted article are his or her own and not an official position of the institution or funder.

References: Authors should provide direct references to original research sources whenever possible. References should not be used by authors, editors, or peer reviewers to promote self-interests. Refer to the journal referencing style downloadable on our *Formatting Requirements* page.

Book Review full structure

Title: The article's full title should contain a maximum of 95 characters (including spaces).

Book details: This should give the full reference to the book you are reviewing (including, year, ISBN, publisher, number of pages, price).

Main text: This should contain the body of the article, and may also be broken into subsections with short, informative headings. Here are some questions you might want to consider:

- Who is the book intended for and does it meet the intended audience's needs?
- What new information does it present and how might it affect readers' practice?
- What evidence does it present and how convincing is it?
- Are the style, organisation and size of the book appropriate for its purpose?
- Are there any studies, facts, or ideas the authors have neglected to consider?
- Would you like to make any further reading suggestions?
- And last, but not least: why should anybody read this book – or why not? Is it regarded as an important book?

Acknowledgements: Those who contributed to the work but do not meet our authorship criteria should be listed in the Acknowledgments with a description of the contribution. Authors are responsible for ensuring that anyone named in the Acknowledgments agrees to be named.

Also provide the following, each under their own heading:

- Competing interests: This section should list specific competing interests associated with any of the authors. If authors declare that no competing interests exist, the article will include a statement to this effect: *The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.* Read our policy on competing interests.
- Author contributions: All authors must meet the criteria for authorship as outlined in the **authorship** policy and **author contribution** statement policies.
- Funding: Provide information on funding if relevant
- Disclaimer: a statement that the views expressed in the submitted article are his or her own and not an official position of the institution or funder.

References: Authors should provide direct references to original research sources whenever possible. References should not be used by authors, editors, or peer reviewers to promote self-interests. Refer to the journal referencing style downloadable on our *Formatting Requirements* page.

Patient Study full structure

Title: The article's full title should contain a maximum of 95 characters (including spaces).

Abstract: The abstract should be no longer than 250 words and must be written in the past tense. The abstract should give a concise account of the Introduction, Patient presentation, Management and outcome and significance of the matter. The abstract can be structured and should consist of four paragraphs labelled Introduction, Patient presentation, Management and outcome, and Conclusion.

- Introduction: Describe the context and the reason for publishing this patient study.
- Patient presentation: Describe your 3-stage assessment of the patient.
- Management and outcome: Describe the management plan, progress and final outcome.
- Conclusion: Summarise the lessons learnt and key implications or recommendations.

Introduction: Convey clearly what is particularly interesting about the patient that you want to describe to the reader. It is useful to begin by placing the study in a historical or social context. If similar cases have been reported previously, please describe them briefly. Clarify your aim or objectives in publishing this patient study.

Ethical considerations: Papers based on a case study that involves the treatment of humans must adhere to the Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects. Specify the recognised ethics committee from which approval for the case study was obtained; also state the serial number of the ethical clearance. Case studies must have the consent of the patient(s) or waiver of consent approved by an ethics committee.

Patient presentation: Describe your patient in detail with consideration of the following aspects:

- Describe the information that was gathered on the patient's medical problem(s) from the consultation, physical examination and results of any investigations.
- Describe the information that was gathered on the patient's perspective of their illness (loss of function, ideas, beliefs, concerns, expectations, or feelings)
- Describe the information that was gathered on the patient's context (family structure and function, occupational issues, environment)
- Provide a 3-stage assessment of the patient's clinical, individual and contextual issues.

Management and outcome: In this section, you should clearly describe the plan for care, as well as the care that was actually provided, how the patient's condition progressed over time and the final outcome.

Discussion: Summarise the key points, lessons learnt and discuss these in relation to the literature. Clarify the implications or recommendations that arise from this patient study.

Acknowledgements: Those who contributed to the work but do not meet our authorship criteria should be listed in the Acknowledgments with a description of the contribution. Authors are responsible for ensuring that anyone named in the Acknowledgments agrees to be named. Also provide the following, each under their own heading:

- Competing interests: This section should list specific competing interests associated with any of the authors. If authors declare that no competing interests exist, the article will include a statement to this effect: *The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.* Read our policy on competing interests.
- Author contributions: All authors must meet the criteria for authorship as outlined in the **authorship** policy and **author contribution** statement policies.
- Funding: Provide information on funding if relevant
- Disclaimer: a statement that the views expressed in the submitted article are his or her own and not an official position of the institution or funder.

References: Authors should provide direct references to original research sources whenever possible. References should not be used by authors, editors, or peer reviewers to promote self-interests. Refer to the journal referencing style downloadable on our *Formatting Requirements* page.

APPENDIXE: G

DECLARATION OF LANGUAGE EDITING

Mari Grobler

Taalpraktisyn /
Language Practitioner

072 929 2036
groblermari@gmail.com

I, Mari Grobler, hereby declare that I have language edited the dissertation with the title:

Physical activity, body composition and handgrip strength among South African young and middle adults: the PURE study

for **Sindi Shozi** for the purpose of submission as a dissertation.

Changes were suggested in the form of electronic track changes and comments. Implementation was left to the discretion of the author.

Please contact me, should there be any questions concerning the language editing of this study.

Yours sincerely

Mari Grobler
SATI membership no: 1002808