Two-year longitudinal changes in body composition, physical activity and TV watching in relation to selected metabolic risk factors: the PAHL study

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DECLARATION

Professor MA Monyeki (promoter and co-author), Professor S Czyz and Professor SJ Moss hereby give permission to the candidate, Mr. V Masocha to include their articles as part of a doctoral thesis. The contribution of each co-author, both supervisory and supportive was kept within reasonable limits and included:

Mr. V Masocha: Developing the proposal, writing the manuscripts, interpretation of the results and compilation of the thesis.

Prof MA Monyeki: Principal investigator of the PAHL Study. Coordinated the study, providing guidance on statistical analyses and interpretation of results, reviewing the manuscript and comments on the thesis.

Prof S Czyz: Contributed to the thesis and article writing.

Prof SJ Moss: Contributed to the article writing.

This thesis is in fulfilment of the requirements for a PhD degree in Human Movement Science within Physical Activity, Sport and Recreation (PhASRec) in the Faculty of Health Sciences at the North-West University.

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Prof MA Monyeki

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ABSTRACT

Childhood obesity and physical inactivity (PI) are serious public health concerns of the twenty-first century. Increased prevalence of obesity and PI contribute to the high morbidity and mortality rates across the globe and have become an extra burden for low-to middle-income countries which are also under the threat of communicable- and poverty-related diseases such as malaria, malnutrition, cholera and infant mortality. It is widely documented that obesity and other metabolic risk factors of cardiovascular diseases (CVDs) in childhood are likely to persist into adulthood. However, there is limited literature on the longitudinal relationship between changes in body composition, physical activity (PA) and metabolic risk factors in relation to television (TV) watching time in children and adolescents in the Tlokwe municipality in the North-West Province of South Africa. Three manuscripts were compiled from this study. The sample of the study included two hundred and eighty-nine (289) adolescent learners (116 boys and 173 girls) from six out of eight schools that agreed to participate in the study. Out of the six schools, two were from areas around the central business district (CBD) comprising mostly adolescents from families of high socio-economic status, and four schools from township areas comprising adolescents from families of lower socio-economic status. Selected learners with a mean age of 14.9±0.76 years in 2011 (at baseline measurement), 15.6±0.77 years in 2012 and 16.4±0.78 years in 2013 participated in the study. School records, as well as participants' birth clinic cards, were used to establish the age of the study participants. Body composition was measured according to the International Society for the Advancement of Kinanthropometry (ISAK) standard procedures. PA level was measured using the International Physical Activity Questionnaire (IPAQ). Abdominal obesity was determined using waist circumference (WC) measurements, and blood pressure (BP) was determined by Omron MIT Elite Plus, while TV watching time was determined through self-reports. The first manuscript examined the two-year longitudinal changes in body composition, PA and selected metabolic risk factors (abdominal obesity and blood pressure) in adolescents aged 14- to 16-years old. Significant mean changes were found for stature, body mass index (BMI), body mass, systolic- (SBP) and diastolic blood pressure (DBP) over the measurements period ($p<0.05$), with girls having consistently greater BMI, the sum of skinfolds and percentage of body fat compared to the boys. Overweight gradually increased by 7.6% (from 12.8% in 2011 to 20.4% in 2013) for the group with more girls (12.2%) being overweight than boys (2.2%), ($p<0.01$). Participation in low physical activity (LPA) increased by 8.2% for the whole group while moderate physical activity (MPA) gradually decreased (15.2%). With regard to the metabolic risk factors, boys had significantly higher WC ($p\leq0.001$) compared to girls. The second manuscript examined the relationship between two-year longitudinal changes in body composition, PA and TV watching among adolescents in adolescents aged 14- to 16-years old. The partial correlation coefficient showed no significant relationship between changes in body composition, PA and TV watching time. However, changes in TV watching time and BMI were both negatively related to changes in MPA and vigorous physical activity (VPA) although the relationship was not statistically significant. After adjusting for age, the regression coefficient indicated a significant

negative relationship between BMI and total physical activity (TPA) among the boys (p=0.02), and between BMI and MPA among the girls (p=0.04). In the third manuscript, the relationship between two-year longitudinal changes in body composition and selected metabolic risk factors in adolescents aged 14- 16-years old was examined. The results indicated that BMI was significantly and positively related to abdominal obesity (r=0.77; p=0.01) and SBP (r=0.26; p<0.05) for the total group. In boys, BMI was significantly and positively related to abdominal obesity (r=0.91; p<0.01) and positive but not significantly related to BP. In girls, BMI was significantly positive and related to abdominal obesity (r=0.49; p<0.01) and to SBP in 2012 (r=0.32; p=0.05) while waist-to-height ratio was positively related to SBP in the 2013 (r=0.23; p=0.05). In conclusion, adolescent girls were more overweight, obese and less physically active compared to the boys over the period. Changes in PA and TV watching have no simultaneous effects on changes in body composition. Both changes in PA negatively, and changes in TV watching positively are independently related to changes in body composition. Age was an important factor in the relationship between changes in body composition and PA. A high BMI and WC significantly increase the likelihood of high BP over a period of time. BMI was a predictor of abdominal obesity in boys while in girls; BMI was a predictor of both abdominal obesity and SBP. School- and community-based strategies that increase PA participation and promote an active lifestyle among adolescents are recommended.

Key Words: body composition, physical activity, television watching, metabolic risk factors, adolescents.

OPSOMMING

Opsomming

Obesiteit en gebrek aan fisieke aktiwiteit (FA) tydens die kinderjare is ernstige openbare gesondheidskwessies wat kommerwekkend is tydens die een-en-twintigste eeu. Die toenemende voorkoms van obesiteit en fisieke onaktiwiteit (FO) dra by tot die hoë syfers van siektes en sterftes dwarsoor die wêreld en dit is 'n bykomende las vir lae tot-middel-inkomste lande, wat ook bedreig word deur oordraagbare en armoed-verwante siektes soos malaria, wanvoeding, cholera en baba-sterftes. Dit is wyd opgeteken dat obesiteit en ander metaboliese risikofaktore t.o.v. kardiovaskulêre siektes (KVDs) wat tydens die kinderjare voorkom, heel waarskynlik sal voortduur tot in volwassenheid. Daar is egter beperkte literatuur oor die longitudinale verhouding tussen veranderinge in liggaamsvorm, FA en metaboliese risikofaktore in verhouding tot die tyd wat spandeer word om televisie te kyk deur kinders en adolessente in die Tlokwe munisipaliteit in die Noord-Wes Provinsie van Suid-Afrika. Drie manuskripte is saamgestel uit die studie. Die steekproef van die studie het tweehonderd nege-en-tagtig (289) adolessente leerders (116 seuns en 173 meisies) uit ses van die agt skole ingesluit wat ingestem het om deel te neem aan die studie. Uit die ses skole, was twee geleë in die sentrale besigheidsdistrik (SBD) en dit het meestal bestaan uit adolessente vanuit gesinne van hoë sosio-ekonomiese status, terwyl die ander vier skole in die townshipsgebiede geleë was en bestaan het uit adolessente vanuit gesinne met laer sosio-ekonomiese status. Gekose leerders met 'n gemiddelde ouderdom van 14.9±0.76 jaar in 2011 (teen basislynmeting), 15.6±0.77 jaar in 2012 en 16.4±0.78 jaar in 2013, het deelgeneem aan die studie. Skoolrekords, asook deelnemers se geboortekliniekkaarte is gebruik om die ouderdom van die deelnemers aan die studie te bepaal. Liggaamsvorm is gemeet volgens die Internasionale Vereniging vir die Bevordering van Kinantropometrie (IVBK) standaardprosedures. FA-vlakke is gemeet deur gebruik te maak van die Internasionale Fisieke-Aktiwiteitsvraelys (IFAV). Abdominale obesiteit is bepaal deur gebruik te maak van middelynomtrekmates (MO) en bloeddruk (BD) is gemeet deur Omron MIT Elite Plus, terwyl die tyd wat spandeer is om televisie te kyk, vasgestel is deur gebruik te maak van verslaggewing deur die deelnemers self. Die eerste manuskrip het die tweejaarlange longitudinale veranderinge in liggaamsvorm, fisieke aktiwiteit (FA) en geselekteerde metaboliese risikofaktore (abdominale obesiteit en bloeddruk) ondersoek. Beduidende gemiddelde veranderinge is gevind t.o.v. statuur, liggaamsmassa-indeks (LMI), liggaamsmassa, sistoliese- (SBD) en diastoliese bloeddruk (DBD) oor die metingstydperk ($p<0.05$), met meisies wat 'n konsekwente hoër LMI gehad het volgens die som van velplooie en die persentasie liggaamsvet in vergelyking met seuns. Oorgewig het geleidelik toegeneem teen

7.6% (vanaf 12.8% om 2011 tot 20.4% in 2013) vir die groep met meer meisies (12.2%) wat oorgewig was as seuns (2.2%), ($p<0.01$). Deelname aan lae fisieke aktiwiteit (LFA) het toegeneem met 8.2% vir die hele groep, terwyl matige fisieke aktiwiteit (MFA) geleidelik afgeneem het (15.2%). Met betrekking tot metaboliese risikofaktore, het seuns 'n beduidende hoër MO ($p \leq 0.001$) in vergelyking met meisies gehad. Die tweede manuskrip het die verhouding tussen tweejaarlange longitudinale veranderinge in liggaamsvorm, FA en televisie-kyktyd onder adolessente gemeet. Die gedeeltelike korrelasiekoëffisiënt het geen beduidende verhouding aangetoon tussen veranderinge in liggaamsvorm, FA en televisie-kyktyd nie. Die veranderinge in televisie-kyktyd en LMI was egter beide negatief verwant tot veranderinge in MFA en kragtige fisieke aktiwiteit (KFA), hoewel die verhouding nie statisties beduidend was nie. Na aanpassing vir ouderdom, het die regressiekoëffisiënt 'n beduidende negatiewe verhouding tussen LMI en die totale fisiese aktiwiteit (TFA) onder seuns ($p=0.02$) en tussen LMI en matige FA onder meisies ($p=0.04$) aangedui. In die derde manuskrip is die verhouding tussen tweejaarlange longitudinale veranderinge in liggaamsvorm en geselekteerde metaboliese risikofaktore ondersoek in adolessente tussen 14- en 16-jaar oud. Die resultate het aangedui dat LMI beduidend en positief verwant was tot abdominale obesiteit ($r=0.77$; $p=0.01$) en SBD ($r=0.26$; $p<0.05$) vir die hele groep. By seuns was LMI beduidend en positief verwant tot abdominale obesiteit ($r=0.91$; $p<0.01$) en positief, maar nie beduidend verwant tot BD nie. By meisies was LMI beduidend positief en verwant tot abdominale obesiteit ($r=0.49$; $p<0.01$) en tot SBD in 2012 ($r=0.32$; $p=0.05$), terwyl middellyn-tot-lengte ratio positief verwant was aan SBD in 2013 ($r=0.23$; $p=0.05$). Gevolglik was adolessente meisies meer oorgewig, vetsugtig en minder FA in vergelyking met die seuns oor dieselfde tydperk. FA en televisie-kyktyd het geen gelyktydige effek op liggaamsvorm nie. Beide FA negatief gesproke en televisie-kyktyd positief gesproke, is onafhanklik verwant tot liggaamsvorm. Ouderdom was 'n belangrike faktor in die verhouding tussen liggaamsvorm en FA. 'n Hoë LMI en MO het die geneigdheid tot hoë BD oor 'n sekere tydperk verhoog. LMI was 'n voorspeller van abdominale obesiteit in seuns, terwyl dit in die geval van meisies beide 'n voorspeller van abdominale obesiteit en SBD was. Skool- en gemeenskapsgebaseerde strategieë wat FA deelname verhoog en 'n aktiewe leefstyl onder adolessente aanmoedig, word aanbeveel.

Sleutelwoorde: liggaamsvorm, fisiekeaktiwiteit, televisie-kyk, metaboliese risikofaktore, adolessente.

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LIST OF ABBREVIATIONS

ACSM	:	American College of Medicine
ADP	:	Air displacement plethysmography
ANOVA	:	Analysis of variance
BIA	:	Bioelectrical impedance analysis
BMI	:	Body mass index
BP	:	Blood pressure
CBD	:	Central business district
CDC	:	Centre for Disease Control and Prevention
CHD	:	Chronic heart diseases
CO_2	:	Carbon dioxide
CT	:	Computed tomography
CVD	:	Cardiovascular disease
Db	:	Body density
DBP	:	Diastolic blood pressure
DEXA	:	Dual-energy X-ray absorptiometry
DLW	:	Doubly labelled water
FM	:	Fat mass
FFM	:	Fat-free mass
GI	:	Gastrointestinal
HBP	:	High blood pressure
HD	:	Hydrodensitometry
HDL-C	:	High-density lipoprotein-cholesterol

HPA	:	High physical activity
HR	:	Heart rate
HW	:	Hydrostatic weighing
IDF	:	International Diabetes Federation
IDL-C	:	Intermediate-density lipoproteins
IGT	:	Impaired glucose tolerance
IOTF	:	International obesity task force
IPAQ	:	International Physical Activity Questionnaire
ISAK	:	International Society for the Advancement of Kinanthropometry
LDL-C	:	Low-density lipoprotein-cholesterol
LPA	:	Low physical activity
METS	:	Metabolic equivalent units
MetS	:	Metabolic syndrome
MPA	:	Moderate physical activity
MRI	:	Magnetic resonance imaging
MVPA	:	Moderate-vigorous physical activity
NAA	:	Neutron activation analysis
NCDs	:	Non-communicable diseases
NCEP/ATP III	:	National Cholesterol Education Program Adult Treatment Panel III
NRF	:	National Research Fund
O_2	:	Oxygen
PA	:	Physical activity
PAEE	:	Physical activity energy expenditure

PAHLs	:	Physical Activity and Health Longitudinal study
PE	:	Physical education
PI	:	Physical inactivity
SANHANES-1	:	South African National Health and Nutrition Examination Survey – 1
SBP	:	Systolic blood pressure
SPSS	:	Statistical Package for Social Sciences
SSF	:	Sum of skinfolds
TEE	:	Total energy expenditure
TBK	:	Total body potassium
TBW	:	Total body water
TC	:	Total cholesterol
TEE	:	Total energy expenditure
TPA	:	Total physical activity
TV	:	Television
UWW	:	Underwater weighing
UNICEF	:	United Nations Children's Educational Fund
VLDL-C	:	Very low-density lipoprotein-cholesterol
VPA	:	Vigorous physical activity
VO_2	:	Oxygen consumption
WC	:	Waist circumference
WHO	:	World Health Organization
WHR	:	Waist-to-hip ratio
WHtR	:	Waist-to-height ratio

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CHAPTER 1:
INTRODUCTION, PROBLEM STATEMENT, PURPOSE, AND HYPOTHESIS OF THE THESIS

1.1 INTRODUCTION

The World Health Organization (WHO) has reported that more than 40 million deaths occur every year due to non-communicable diseases (NCDs), and more than 82% of these deaths occur in low-to-middle-income countries (WHO, 2012; Niessen *et al.,* 2018:2036). A 47% global prevalence rate of childhood overweight and obesity (combined) was noted from 1980 to 2013 (Ng *et al.*, 2014). This increased prevalence of obesity has become an extra burden in some countries especially in Africa, which are under threat of infectious diseases, poverty and infant mortality (Adeboye *et al.,* 2012). Obesity coexists with other metabolic risk factors such as high blood pressure (BP), type two diabetes mellitus (DM) and insulin resistance (Eckel *et al.,* 2011; Rivers *et al.*, 2014). In a report by Lancet in 2015, it was stated that 1.6 million deaths annually could be attributed to insufficient physical activity (PA) (GBD 2015 Risk Factors Collaborators, 2016). Sedentary behaviour such as television (TV) watching, computer video game playing and physical inactivity (PI) are some of the risk factors of obesity prevalence in children and adolescents. This is worrisome given the fact that childhood obesity may track into adulthood (Proctor *et al.,* 2003; Herman *et al.,* 2009; Evensen *et al.*, 2016). Childhood refers to a person age 19 or younger, and defines an adolescent as any person between ages 10 and 19 (World Health Organization (WHO), 2018). As such and by definition of adolescent, the focuse of this study was on adolescent between the ages 14- and 16-year-old. It has been stated that adolescent is a critical time in life when people becomes independent individuals' forge new relationships, develop new social skills, and learn behaviours that will last for the rest of their lives. And, adolescent can be the most challenging period (WHO, 2018).

1.2 PROBLEM STATEMENT

Both cross-sectional (Mantsena *et al.*, 2003:225; Micklesfield *et al.,* 2014:14; Toriola & Monyeki, 2012:796; Moselakgomo *et al.*, 2015:730) and longitudinal data (Monyeki *et al.,* 2005:877; Pienaar, 2015:2; Toriola & Monyeki, 2015) on South African children and adolescents revealed that physical activity (PA) levels are gradually declining and obesity is on the rise. Similar findings from large national studies have also been reported (Reddy *et al.,* 2012:262; Uys *et al.*, 2016:265). Given this background, this could mean that South African children and adolescents have a higher chance of developing individual or clustered metabolic risk factors and subsequently cardiovascular disease (CVD). Of concern is the fact that a survey on South African national youth risk behaviour revealed that 37.5% of South African adolescent learners are insufficiently physically active (Reddy *et al.,*

2003:63–66). The report further revealed that physical education (PE) was neglected in most public schools, most of which have been constructed without playing grounds (Reddy *et al.,* 2003:63–66). These matters need urgent attention in order to reduce PI and the risks of developing chronic weight-related diseases that are becoming prevalent among the youth.

A variation in PA levels among South African children and adolescents from different ethnic groups was reported (Reddy *et al.,* 2003:64; Engelbrecht *et al.,* 2004:44; Malhotra *et al.,* 2008:315; Wushe *et al.,* 2014:2). Findings from these studies have shown that black children were insufficiently physically active compared to white children. Children and adolescents from farming areas (Prinsloo & Pienaar, 2003:151) and rural areas (Monyeki *et al.,* 2005b:58; Moselakgomo *et al.,* 2014:347) were more physically active compared to their counterparts from urban areas. This means that urban children and adolescents could be predisposed to a higher risk of developing obesity and related metabolic illnesses compared to their rural- and farm counterparts.

Incidents of overweight and obesity in South Africa have been reported among children and adolescents (Puoane *et al.*, 2002:1041; Mantsena *et al.*, 2003:225; Monyeki *et al.*, 2005:877; Zeelie *et al.*, 2010:285; Kimani-Murage *et al.*, 2010:1; Toriola & Monyeki, 2012:796; Micklesfield *et al.*, 2014:14; Moselakgomo *et al.*, 2014:343; Pedro *et al.,* 2014:194; Pienaar, 2015:2; Moselakgomo *et al.*, 2015:730). In relation to the rising incidence of obesity, a combined prevalence rate of metabolic syndrome (MetS) of between 55.4–62% was reported among children and adolescents from Cape Town (Erasmus *et al.*, 2012:841). A recent study (Sekokotla *et al.*, 2017:134) found that adolescent girls from Mthatha in the Eastern Cape Province had a higher prevalence of risk factors for MetS compared to adolescent boys. MetS is defined by a constellation of interconnected physiological, biochemical, clinical, and metabolic factors that directly increase the risk of atherosclerotic cardiovascular disease and type 2 diabetes mellitus (Kaur, 2014:13). The components used in the diagnosis of MetS include increased waist circumference, elevated fasting triglycerides, elevated fasting glucose, elevated systolic blood pressure, elevated diastolic blood pressure and decreased levels of high-density lipoprotein-cholesterol (HDL-C) (Corte *et al.*, 2015:49). Based on the scope and financial constraints for this study selected MetS (i.e. abdominal obesity and BP) are studied in relation with body composition and PA.

According to Caspersen *et al.* (1985:126), PA includes any form of bodily movement that results in energy expenditure – such as walking, running, jogging, cycling – and is quantified according to the intensity of the activity as being either low, moderate or high/vigorous and positively associated with physical fitness (ACSM; 2009:22). MetS is defined as a combination of three or more coexisting metabolic risk factors, such as abdominal obesity, lipid disorders, insulin resistance, impaired glucose tolerance and elevated BP (Moreira *et al.,* 2011:1; Nikolopoulou *et al.,* 2012:935; Gierach *et al.,* 2014:2).

Studies have reported an association between PA, TV watching and metabolic risk factors (Owen, 2012; Melkevik *et al.,* 2015; Pearson *et al.,* 2017). Spending less time on moderate-vigorous physical activity (MVPA) combined with long hours (i.e. more than three (3) hours per day) watching TV and other screen-related activities is associated with an increased risk of obesity and the prevalence of other causes of mortality and morbidity such as CVDs (Tremblay *et al.,* 2011; French *et al.,* 2012). As such, increasing participation in MVPA improves fat oxidation and other determinants of obesity (Katzmarzyk *et al.,* 2015; Melkevik *et al.,* 2015), consequently reducing the risk of developing obesity-related diseases.

Several governments and non-governmental organisations have drafted PA guidelines aimed at improving the quality of life and reducing/preventing the development of chronic metabolic diseases among the citizenry. It has been recommended that people should accrue at least one hour per day of MVPA for at least three days a week in order to improve the quality of life (ACSM, 2009; Center for Disease Control and Prevention (CDC), 2009; WHO, 2010). The Canadian Society for Exercise Physiology (2011) proposed that children and adolescents between the ages 5–17 years should accrue at least 60 minutes of MVPA daily and this should include vigorous-intensity activities for at least three days per week. Alternatively, a daily step count of between 10,000 and 12,500 steps is commendably beneficial in improving the quality of life Tudor-Locke *et al.* (2011:3). Despite these recommendations, South African children and adolescents remain physically inactive exposing themselves to the risks of CVDs.

It can be observed from the literature that there is a link between body composition, PA and TV watching time with selected metabolic risk factors. This study, therefore, seeks to explore answers to the following research questions:

(i) What are the longitudinal changes in body composition, PA and selected metabolic risk factors (i.e. abdominal obesity and BP) among adolescents from the Tlokwe municipality in the North West Province of South Africa?

(ii) What are the relationships between two-year longitudinal changes in body composition, PA and TV watching time among adolescents from the Tlokwe municipality in the North West Province of South Africa?

(iii) What are the two-year longitudinal relationships between changes in body composition and selected metabolic risk factors (i.e. abdominal obesity and BP) among adolescents from the Tlokwe municipality in the North West Province of South Africa?

With answers to these questions, the present study aims to contribute on the scientific knowledge of the relationships between changes in body composition (BMI, waist-to-height ratio (WHtR), percentage

body fat), PA patterns in relation to changes in TV watching time, and selected metabolic risk factors (abdominal obesity and BP). Additionally, it will help parents by providing scientific information regarding how to minimise children's overweight by possibly reducing TV watching time and encouraging them to undertake regular PA in order to combat obesity.

1.3 OBJECTIVES

The objectives of this study are to determine:

(i) Longitudinal changes in body composition, PA and selected metabolic risk factors (i.e. abdominal obesity and BP) among adolescents from the Tlokwe municipality in the North West Province of South Africa.

(ii) The relationship between two-year longitudinal changes in body composition, PA and TV watching time among adolescents from the Tlokwe municipality in the North West Province of South Africa.

(iii) The two-year longitudinal relationship between changes in body composition and selected metabolic risk factors (i.e. abdominal obesity and BP) among adolescents from the Tlokwe municipality in the North West Province of South Africa.

1.4 HYPOTHESIS

This study was based on the following hypotheses:

(i) There will be significant two-year longitudinal changes in body composition, PA and selected metabolic risk factors (abdominal obesity and BP) among adolescents from the Tlokwe municipality in the North West Province.

(ii) There will be a significant positive relationship between two-year longitudinal changes in body composition, TV watching time and PA among adolescents from the Tlokwe municipality in the North West Province.

(iii) There will exist significant positive relationships between two-year longitudinal changes in body composition and selected metabolic risk factors (abdominal obesity and BP) among adolescents from the Tlokwe municpaliy in the North West Province.

1.5 STRUCTURE OF THE THESIS

The thesis is submitted in article format as approved by the North-West University Senate in the following format:

Chapter 1: Introduction – This chapter encompasses the problem statement, the purpose of the study and the hypothesis of the study, as well as the structure of the thesis. A list of references has been provided at the end of the chapter in accordance with the guidelines of the North-West University.

Chapter 2: Literature Review – This chapter covers an overview of the related literature on body composition, PA, TV watching time and selected metabolic risk factors among adolescents and the knowledge gaps in these areas. A list of references has been provided at the end of the chapter in accordance with the guidelines of the North-West University.

Chapter 3: Article 1 - Two-year changes in body composition, PA and selected metabolic risk factors among adolescents living in Tlokwe Municipality of the North West Province, South Africa: the PAHL study. This article was published in the *South African Journal for Research in Sport, Physical Education, and Recreation (Vol 40(2), 99-114, 2018).* Results described in this manuscript were also partially presented at the 17th Biennial Congress of the South African Sports Medicine Association (SASMA): 24 – 27 October 2017. A list of references has been provided at the end of the chapter in accordance with the guidelines of the specific journal.

Chapter 4: Article 2 – Two-year relationship between changes in body composition, PA and TV watching time among adolescents from North West Province of South Africa: the PAHL study. This article will be submitted to *The African Journal for Physical Activity and Health Sciences.* A list of references has been provided at the end of the chapter in accordance with the guidelines of the specific journal.

Chapter 5: Article 3 – The two-year longitudinal relationship between changes in body composition and changes in selected metabolic risk factors (abdominal obesity and BP) among adolescents from Tlokwe municipaltiy in the North West Province of South Africa. This article will be submitted to the *International Journal of Environmental Research and Public Health.* A list of references has been provided at the end of the chapter in accordance with the guidelines of the specific journal.

Chapter 6: Summary, conclusions, limitations, and recommendations. A list of references has been provided at the end of the chapter in accordance with the guidelines of the North-West University.

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CHAPTER 2:
LITERATURE REVIEW – BODY COMPOSITION, PHYSICAL ACTIVITY, AND METABOLIC RISK FACTORS.

2.1 INTRODUCTION

Physical inactivity (PI) and sedentary behaviour account for an increase in unhealthy body composition components such as percentage body fat (%BF), body mass index (BMI) and waist-to-hip ratio (WHR) (Kruger *et al*., 2002:422; Ara *et al*., 2004:1587; Weinstein *et al*., 2004:1188; Kruger *et al*., 2006:357). The excessiveness of these body composition variables has been widely established as a contributor to overweight and obesity (Must & Tybor, 2005:85; Goldfield, 2009:463; Owen *et al*., 2010:105; Moreira *et al*., 2011:1; Pienaar, 2015:8). Obesity has been widely linked to the development of many chronic diseases such as cardiovascular diseases (CVDs), strokes, type two diabetes mellitus (DM), coronary heart diseases and some forms of cancer (Proctor *et al.*, 2003:827; Brage *et al.*, 2004:1503; Warburton *et al*., 2006:801; Wittmeier *et al*., 2007:218; Bhuiyan *et al*., 2013:2). The WHO system defines overweight as a BMI > 1 SD and obesity as a BMI > 2 SD, corresponding to 97.7 percentile from the WHO reference population (De Onis & Lobstein, 2010:459; Cole *et al.*, 2012:289). The IOTF cutoff is an extrapolation of the adult BMI cutoff points for obesity (30 kg/m2) (De Onis, 2007:662).

Early epidemiological studies on physical activity (PA) and chronic diseases focused mainly on adult population (Sallis *et al*., 1988:933–941; Berlin & Colditz, 1990:612; Manson *et al.*, 1990:882–9; Owens *et al*., 1990:147–157; Manson *et al.*, 1991:774–778; Goran, 2001:158–71; Ford *et al*., 2002:356–9). Recently, more attention has been shifted to children and adolescents (Reddy *et al.*, 2012:262–8; Monyeki *et al*., 2012:1–8; Ng *et al*., 2013:766–81; Welisch *et al*., 2013:848–53; Pienaar, 2015:1–10; Sekokotla *et al*., 2017:131–137). Childhood refers to a person age 19 or younger, and defines an adolescent as any person between ages 10 and 19 (World Health Organization (WHO), 2018). As such and by definition of adolescent, the focuse of this study was on adolescent between the ages 14- and 16-year-old. It has been stated that adolescent is a critical time in life when people becomes independent individuals' forge new relationships, develop new social skills, and learn behaviours that will last for the rest of their lives. And, adolescent can be the most challenging period (WHO, 2018). This shift in approach may yield positive results towards the prevention of metabolic-related chronic diseases given the fact that many studies have reported that many risk factors of these diseases mostly originate in the childhood and adolescence stages when permanent lifestyle behaviour becomes established (Kaur, 2014).

Traditionally, the active play has been an integral part of childhood life. Today the desire for outdoor play among children and adolescents has been overshadowed by television (TV) (Gomez *et al*., 2007:2; Datar *et al*., 2013:1066) and computer game playing (Hansen & Sanders 2011:124). TV watching time and computer video game playing have become the leading forms of leisure time activity among children and adolescents of today. The increase in PI and obesity has been blamed on excessive time spent infront of the TV and/or computer video game playing among other causes (Wiecha *et al*., 2006:436; Gomez *et al.,* 2007:2; Hansen & Sanders, 2011:124; Datar *et al*., 2013:1066). Long hours of TV watching can result in lower total energy expenditure (TEE) (Proctor *et al*., 2003:830), hence Ekelund *et al.* (2006:2450) warned that prolonged TV watching time is a risk factor linked to overweight and obesity which is an antecedent of several chronic lifestyle diseases. Besides time spent infront of the TV, Wiecha *et al*. (2006:436) noted that TV advertisements of unhealthy foods also induce uncontrolled eating habits, which can result in high-energy intake among children and adolescents thereby contributing to overweight and obesity. Increased use of automobiles, (Owen *et al*., 2010:105; Draper *et al*., 2014:101) urbanisation and poor nutritional habits (Zimmet *et al*., 2007:300; Rossouw *et al*., 2012:5; Reddy *et al*., 2012:266), have also been noted as high contributors to overweight and obesity across the globe, resulting in the increased prevalence of non-communicable diseases (NCDs) of lifestyle. PA has been reported to prevent and reduce the incidence of obesity, and helps to achieve and maintain healthy body composition among children as well as preventing the inception of chronic metabolic disorders (Must & Tybor 2005:85; Ekelund *et al*., 2006:2450; WHO, 2009; Mamabolo *et al*., 2014:194; Willis *et al*., 2015:76). In this regard, engaging in regular PA, reducing time spent on sedentary behaviour and modifying dietary and nutritional behaviour could be the most effective intervention strategies to reduce the risk factors of chronic diseases (WHO, 2009; Dishman *et al*., 2013:52; Ng *et al*., 2014:766).

There is an inverse association between PA levels with time spent watching TV, obesity and the risk of metabolic-related illnesses among children and adults (Gortmaker *et al*., 1996:356; Ekelund *et al*., 2006:2451; Jackson *et al*., 2009:1031; Liao *et al*., 2013:588; Herrick *et al*., 2014:4). It has been reported that excessive fatness is positively linked to prolonged hours of TV watching (Swinburn & Shelly, 2008:132; Drenowatz *et al*., 2016:486). Although studies have shown that changes in PA and TV watching time are linked to changes in body composition and influence the development of risk of metabolic risk factors of metabolic diseases, most of these studies used cross-sectional designs. There are limited studies in this area that examine these changes and inter-relationships using longitudinal designs.

This chapter focuses on a review of related literature under the following headings:

- Body composition assessment

- Physical activity in children and adolescents
- Selected metabolic risk factors in children and adolescents
- Role of PA in the prevention of NCDs
- Determinants of PA participation at childhood and adolescence
- Relationship between changes in body composition, PA, and TV watching time
- Relationship between body composition, PA, and selected metabolic risk factors

2.2 BODY COMPOSITION ASSESSMENT

Body composition is defined as a quantitative description of measures of fat and fat-free components of the body (Heyward & Wagner, 2004:4) and is one of the important bioindicators of health status among children and adolescents (Monyeki *et al.,* 2005:878). The proportions of fat and fat-free components have significant implications on an individual's present health status and can be used to predict future health-related outcomes such as CVDs, nutritional and psychological status as well as physical fitness (Allison *et al.,* 2007:97). While fat is an essential component of the human body in maintaining normal physiological functions and homeostasis, several studies have consistently reported that excessive body fat is detrimental to health as it is associated with reduced PA and physical fitness (Monyeki *et al.,* 2007:557); obesity and high risk of metabolic illnesses such as coronary heart disease, diabetes mellitus, cancers, strokes (Rizzo *et al.,* 2008:586; Bhuiyan *et al.,* 2013:1; Pollock, 2015:54; Jung *et al.,* 2016:675). Changes in body composition can be influenced by several factors ranging from disease, PA, gender, age, nutrition and lifestyle factors, biological maturation, genetics and ethnicity (Bouchard, 1993:6; Malina *et al.,* 2004:101; Pahkala, 2009:14). Assessment of body composition changes among children and adolescents is very important because it enables the early identification of children with abnormal body composition trends and facilitates a timeous and informed management of such trends. Adolescence is the critical stage in life at which permanent behavioural changes take place (Malina 2001:4; WHO, 2016) therefore monitoring of body composition changes could help adolescents to adopt appropriate dietary and physically active interventions that can help reduce the risk of developing chronic diseases later in life (Andersen *et al.,* 1998:939; Proctor *et al.,* 2003:827; Strong *et al.,* 2005:732).

2.2.1 Body composition models

Body composition models are theoretical models based on the chemical analysis of organs whereby fat, total body water, mineral (bone and soft tissue) and protein content of the body are estimated (Withers

et al., 1998:244). There are a number of models that can be used in assessing human body composition, namely the:

- ***Two-component (2-C) model*** which divides the human body mass into two components, i.e. fat mass (FM) and fat-free mass (FFM) or lean (Withers *et al.*, 1998:238);
- ***Three component (3-C) model*** which divides the human body into three components, namely fat, water and solids, the latter which include protein and mineral fractions of the FFM combined (Silva *et al.*, 2004:962); and
- ***Four component (4-C) model*** that is considered the 'golden standard' in body composition.

In the 4-C model, the body is divided into four fractions, namely fat, water, mineral and protein (Wang *et al.*, 2008:173). The 4-C models have greater accuracy in estimating percentage body fat (%BF) compared to the 2-C and 3-C models (Withers *et al.*, 1998:238; Wang *et al.*, 2008:173). The ***six component (6-C) model*** (atomic model) allows the direct analysis of the chemical composition of the body using the Neutron Activation Analysis (NAA) (Heymsfield *et al.*, 2015:283). It divides the human body into six fractions, namely water, nitrogen, calcium, potassium, sodium, and chloride. The 6-C model is more accurate compared to all the other body composition assessment models, but it is expensive and can expose the individual to radiation that may have harmful effects to health (Heyward & Wagner, 2004:4).

2.2.2 Methods of body composition assessment

Body composition can be assessed at the atomic, cellular, molecular and tissue levels (Duren *et al.*, 2008:1140). Assessment at the atomic level quantifies the basic elements like carbon, calcium, potassium, and hydrogen. At the molecular level, assessment is based on the amounts of water, protein and fat; the cellular level assessment is based on extracellular fluids and body cell mass, while at the tissue level the assessment is based on the amounts and distribution of adipose, skeletal and muscle tissues (Heymsfield *et al.*, 2015:283).

2.2.2.1 Direct methods of body composition assessment

Body composition analysis at the atomic and the cellular levels is done through direct methods such as neutron activation analysis (NAA), isotope dilution, and total body count of potassium (TBK). Indirect assessment methods include anthropometry and bioelectrical impedance analysis (BIA) which only provide estimates of indices of body composition. The criterion methods measure and describe body properties, such as density, amount and distribution of adipose tissue, skeletal and muscle tissues using advanced body composition assessment methods such as densitometry, computed tomography (CT),

magnetic resonance imaging (MRI), and dual-energy x-ray absorptiometry (DEXA) (Duren *et al.*, 2008:1140).

(i) **Neutron Activation Analysis (NAA).** The NAA method measures human body composition at an atomic level by passing a neutron beam through the person's body which forms isotopes and emits gamma rays; the quantity of each element is then determined by measuring its emissions (Sergi *et al.*, 2006:180). NAA can be used to measure the total body content of oxygen, carbon, calcium, sodium, chloride, hydrogen, nitrogen and phosphorous. The NAA is the most sophisticated technology of assessing body composition but its use is restricted by the cost of the equipment and facilities, as well as limited expertise in this technology (Heyward & Wegner, 2004:4).

(ii) **Isotope dilution**. Isotopic dilution is one of the standard techniques for measuring total body water (TBW) and extracellular water (ECW). The techniques allow the evaluation of FM and FFM, assuming that the hydration of FFM or TBW is constant (i.e. TBW/ FFM = 0.73) (Sergi *et al.*, 2006:180; Lee & Gallagher 2008:566). This method is because water has a stable relationship with FFM (Duren *et al.*, 2008:1142) and it constitutes the larger percentage of FFM.

(iii) **Total body potassium count (TBK)** is another direct method of body composition assessment which measures the amount of naturally radioactive potassium in the body (Duren *et al.*, 2008:1142). The method relies on the fact that potassium is stored intracellularly; hence, measuring potassium content can provide an estimate of body cell mass. Total body potassium count can be quantified by measuring the gamma rays emitted by naturally occurring isotopes via a whole body counter (Heyward & Wagner 2004:44). Once the TBK has been determined, FFM can be calculated based on the assumption that potassium concentration in FFM is constant (Ellis, 1996:45; Murphy *et al.*, 2014:153).

2.2.2.2 Indirect methods

(i) **Anthropometry**: Anthropometry is the most common field method for body composition assessment. The method relies on the assessment of the **skinfolds (SKF)**, taken from various measurement sites on the body (Heyward & Wagner 2004:49). SKF are an indirect method of measuring the thickness of subcutaneous adipose tissue which is then used to estimate the total body density from which percentage BF can be calculated through generalised, population- or age-specific equations (Carter & Heath, 1991; Duren *et al.*, 2008:1140). The SKF technique is inexpensive and easy to use and is the most preferred method for large-scale epidemiological surveys (Wells & Fewrell, 2006:615).

(ii) **Bioelectrical impedance analysis (BIA)** is a non-invasive technique used to assess body composition that involves the application of a low level electrical current through a person's body (Wells & Fewtrell, 2006:613) which measures the resistance of the body tissue to the electrical current (Wright *et al.*, 2008:211). Fat tissue has higher electrical impedance due to its poor conductivity. Conversely, low resistance to electrical current flow is found in lean tissue, which is a good conductor of electrical current due to its high water content (Bera, 2014:7). The BIA method uses generalised equations and population-specific equations to predict the %BF of the client (Heyward & Wegner, 2004). The BIA method is relatively inexpensive to perform, is non-invasive and painless, and requires minimum operator training (Saxena & Sharma, 2004:63).

2.2.2.3 Criterion methods

(i) **Hydrodensitometry (HD)** is also known as hydrostatic weighing (HW) or underwater weighing (UWW). It is a technique that estimates body composition using measures of body weight, body volume and residual lung volume (Duren *et al.*, 2008:1142). The HD technique is more precise in measuring body volume compared to other body composition assessment methods because it considers the residual volumes of the lungs and the gastrointestinal (GI) tract in computing the body volume and body density of an individual (Heyward & Wagner, 2004:30). However, the HD method is particularly problematic in children and obese people because it is difficult for them to submerge completely under water (Duren *et al.*, 2008:1142).

(ii) **Air Displacement Plethysmography (ADP)** is another criterion assessment method which measures body volume and Db in the same way as HD. However, in the case of ADP, the air displacement technique is used to estimate body volume rather than water displacement as in the case of HD. The modern ADP method uses the BodPod® fibreglass chamber, which depends on air displacement and pressure-volume relationships to derive body volume (Heyward & Wagner, 2004:33). Body volume is determined from the changes in pressure inside the chamber and is based on Boyle's law, which states that 'the volume and pressure of an object are inversely related' (Fields *et al.*, 2002:454). The ADP technique is quick and demands minimal compliance by the client as well as minimum technical skills to administer the test (Heyward & Wagner, 2004:33**).**

(iii) **Dual-Energy X-ray Absorptiometry (DEXA)** is one of the popular techniques of quantifying fat, lean, and bone tissues (Duren *et al.*, 2008. 1143). This technique can assess regional/segmental body composition and can provide separate estimates of total FFM excluding bone mass, FM and %BF by attenuating X-rays with low or high photon energies depending on the thickness, density and chemical composition of the underlying tissue (Heyward & Wagner, 2004:40; Lee & Gallagher, 2008:569). The use of DEXA techniques is not recommended for

individuals whose body dimensions exceed the length or width of the scanning bed as it may give inaccurate results (Silva *et al.*, 2004:962).

(iv) Computed tomography (CT) and Magnetic Resonance Imaging (MRI) are radiological methods that can be used to estimate body volume. The techniques primarily determine hydrogen nuclei located either in water or fat and use these data to differentiate tissue types in 'imaging slices' which can then be summed to calculate regional tissue volumes (Wells & Fewrell, 2006:614). A computer-generated image formed from the X-ray beams allows the recognition of bone, fat tissue, and fat-free tissue separately. However, the methods are recommended when assessing regional body composition and not the whole body due to exposure to radiation, which could be harmful to the client (Heyward & Wagner, 2004:44).

2.3 PHYSICAL ACTIVITY IN CHILDREN AND ADOLESCENTS

PA is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen *et al.*, 1985:126). It involves activities such as walking, running, jogging, cycling and playing sport as well as household chores, and is quantified according to the intensity of the activity as being either inactive, low, moderate or high/vigorous (Dishman *et al.*, 2013:10). Pate *et al.* (2008:174), describe being physically inactivate or sedentary behaviour as being frequently engaged in activities that do not increase energy expenditure substantially above the resting metabolic level, or doing activities which constitute less energy expenditure ranging from 1.0–1.5 metabolic equivalent units (METS), including activities such as sitting at home or on automobiles, sleeping, lying down, reading, watching TV and other forms of screen-based entertainment. Evaluated in terms of oxygen consumption, sedentary behaviour includes activities that require oxygen uptake of up to 3.5 ml/kg/min (Pate *et al.*, 2008:174). Physical activity is critical for children's normal growth and development and is a key determinant of energy expenditure and weight control; however, statistics on global PA (WHO, 2010) revealed that more than 80% of school-going young boys and girls (11–17 years) are insufficiently active. The World Health Organization (WHO, 2010) further reported that Africa and the Eastern Mediterranean and Western Pacific regions had the highest averages of insufficiently active adolescents (above 85%) while South East Asia had the least (73.4%). The United Nations International Children's Emergency Fund (UNICEF) (2012:18) reported that avoiding PA is one of the behaviours often established in adolescence (together with smoking and drug abuse) that account for two-thirds of premature deaths and one-third of the total disease burden later in adulthood.

Cross-sectional data on South African children and adolescents revealed that PA levels are gradually declining (Mantsena *et al.*, 2003:225; Reddy *et al.*, 2003:64; Monyeki *et al.*, 2005:877; Micklesfield *et al.*, 2014:14; Toriola & Monyeki, 2012:796; Reddy *et al.*, 2012:262; Pienaar, 2015:2; Uys *et al.*, 2016:265). This could mean that South African children and adolescents are at a high risk of CVD and

other chronic illnesses. The South African National Youth Risk Behaviour Survey revealed that 37.5% of South African adolescent learners are insufficiently physically active (Reddy *et al.*, 2003:63–66). In addition, a variation in PA level among South Africa children from different ethnic groups was reported (Reddy *et al.*, 2003:64; Engelbrecht *et al.*, 2004:44; Malhotra *et al.*, 2008:315; Wushe *et al.*, 2014:2). A snap observation from these studies was that black children were insufficiently physically active compared to white children. In one of the studies, Engelbrecht *et al.* (2004:44) noted a different PA pattern among the different racial groups in the North West Province and reported that Indian girls (94%) were the least active, followed by coloured girls (87.5%), black girls (72.9%) and white girls (61%). Wushe *et al.* (2014:2) reported similar findings among adolescents in Potchefstroom in the same province. Children and adolescents who reside in farming areas (Prinsloo & Pienaar, 2003:151) and rural areas (Monyeki *et al.*, 2005b:58; Moselakgomo *et al.*, 2014:347) are more physically active compared to their counterparts from urban areas. Most of these children walk long distances to school because they have limited financial resources for commercial transport, and they perform household chores such as digging the garden, work in the fields, and regularly play traditional games which keep them active and fit (Monyeki *et al.*, 2005b:58).

2.3.1 Changes in PA patterns among children and adolescents

A plethora of studies agree that PA levels among children decrease with age (Gordon-Larsen *et al.*, 2004:218; Bruner *et al.*, 2009:426; Hallal *et al.*, 2012:247; American College of Sports Medicine (ACSM), 2015). In childhood, participation in PA is reported to be high and tends to diminish as the child advances into adolescence and adulthood (Caspersen *et al.*, 2000:1601; Thompson *et al.*, 2003:1684; Nelson *et al.*, 2005:259; ACSM, 2015). Data from the global PA level survey revealed that the number of children who met the global daily PA recommendations in WHO member countries decreased as children progressed towards adolescence and adulthood (Hallal *et al.*, 2012:253). For instance, among the US population it was reported that while more than 50% of children between the age of 6–11 years met the Federal Government daily PA recommendations, less than 20% of adolescents (12–15 years), 10% of adolescents (16–19 years) and 5% of adults (20–60 years) met the PA recommendations (Troiano *et al.*, 2008:185).

Gender variation in the rate of decline in PA was noted between boys and girls (Caspersen *et al.*, 2000:1601; Armstrong & Welsman, 2006:1076; Allison *et al.*, 2007:99; Hallal *et al.*, 2012:250; ACSM 2015). A rapid decline in PA participation and physical fitness level was more pronounced among girls than boys as age increases. Evidence has also shown that boys are physically more active compared to girls, a tendency largely reported in the literature (Koorts *et al.*, 2011:1060; De Vos *et al.*, 2016:375; Telford *et al.*, 2016:7). A study by Armstrong *et al.* (2000:775) in the United Kingdom revealed that 76.2% of boys accumulated the recommended PA level at the age of 11 years, but by the age of 13 only 44.4% of the boys met the target, while among the girls the decline was even greater, from 73.5% (11

years) to 31.6% (13 years). In another study (SPEEDY study), Brooke *et al.* (2014:4) found that at the age of 10 years children participated in a wide range of physical activities and games, however by the age of 14, both boys and girls had dropped out of at least 75% of all the activities and games reported at age 10 years. Studies on South African children and adolescents have reported similar trends (Reddy *et al.*, 2003:64; Amusa *et al.*, 2010:221; Walter, 2011:785; Draper *et al.*, 2014:98; McVeigh & Meiring, 2014:371; Micklesfield *et al.*, 2014:5; De Vos *et al.*, 2016:375). The continuous downward trend in PA participation has become a cause of concern for many countries across the world given the fact that it may lead to the development of serious weight disorders (i.e. BMI >25) and the risk of developing irreversible health problems, disability and premature mortality later in life.

2.3.2 Physical activity assessment

Various PA assessment methods can be applied in different settings and on different populations. Armstrong and Welsman (2006:1069) suggested that any assessment method should be socially acceptable and should minimally influence the individual's normal PA pattern. PA measurement methods can be categorised as subjective (self-report, interview, proxy report, and diary) or objective (doubly labelled water, indirect calorimetry, direct observation, heart rate monitoring, pedometry, and accelerometry) (Sirard & Pate, 2001:441; Armstrong & Welsman, 2006:1069).

(i) Subjective PA assessment methods.

Self-report is the most commonly used method of PA assessment particularly in large epidemiological studies due to its cost-effectiveness and ease of implementation (Armstrong & Welsman, 2006:1070). Self-report can be in the form of retrospective/recall questionnaires, recall interviews and activity diaries or mail surveys (Armstrong & Welsman, 2006:1070). Although they are widely used, less expensive and easy to implement, self-reports are subjective to errors of measurement as the participant may tend to misrepresent their PA levels leading to over- or under-reported results (Sirard & Pate, 2001:448). The International PA questionnaire (IPAQ) (WHO, 2002; CDC, 2002) has been widely recognised as a valid instrument for PA assessment among adolescents and adults. The short form consists of seven recall questions on frequency and duration spent in sedentary behaviour and MVPA during the past seven days. The IPAQ short form was compared to accelerometers, and overall averages of 0.76 (reliability) and 0.33 (validity) were confirmed across 12 countries (Craig *et al.*, 2003:1385). PA ***interviews*** have similar strengths and limitations as self-report measures (Sirard & Pate, 2001:450). Studies that involve children below the age of 12 normally use ***proxy reports*** by parents, teachers or their caregivers because children at this age are presumed to be less time conscious, have lower cognitive functioning and tend to engage in PA sporadically and at varying intensities, making it difficult to fully recall their activity diaries (Pate *et al.*, 1993:321). Significant positive correlations were observed between proxy report PA scores and objectively measured total PA

(r = 0.30; p < 0.01) and MVPA (r = 0.34; p < 0.01) (Rice *et al.*, 2013:396). While the use of parents and teachers as proxy respondents could help to reduce recall errors that could arise from children's cognitive limitations, Armstrong and Welsman (2006:1070) argued that it is not always guaranteed that parents or teachers can provide an accurate assessment of their children.

The ***PA diary*** is considered one of the most accurate subjective techniques for PA assessment. Although it is quite burdensome for the participant to keep a diary, the method is suitable for adolescent and adult participants other than children under the age of ten years (Sirard & Pate, 2001:450).

(ii) Objective PA assessment methods.

The ***doubly labelled water*** **(DLW)** method is one of the objective methods of assessing daily energy expenditure by estimating carbon dioxide (CO_2) production using isotope dilution for a minimum period of three days (Armstrong & Welsman, 2006:1073) and a maximum period of 14 days (Ekelund *et al.*, 2001:276; Sirard & Pate, 2001:443; Loprinzi & Cardinal, 2011:21). The difference between CO_2 and hydrogen elimination rates from the body water can then be used to estimate the total energy expenditure (TEE) by using either a known or an estimated respiratory quotient (Schoeller & Hnilicka, 1996:348; Buchowski, 2014:573). The method is suitable for use in free-living participant (i.e. those being researched in their normal daily lives as opposed to laboratory conditions) (Sirard & Pate, 2001:450). However, there are limited studies that used the DLW technique in children (Sirard & Pate, 2001:443). The advantage of the DLW method is that it provides a direct estimate of CO_2 production, it can be easily applied in the field and can be used in both children and adults (Butler *et al.*, 2004:173). There is no need for reliance on the participant to do anything besides drinking the labelled water and provide timed urine samples (DeLany, 2008:88). However, the limitations of the DLW method are that isotopes are expensive and difficult to obtain and thus cannot be used in large epidemiological studies (Sirard & Pate, 2001:450). The method requires that measurements be taken for at least three days – any less renders the data invalid – and it can only determine TEE and not hourly or daily energy expenditure (Sirard & Pate, 2001:450; Ainslie *et al.*, 2003:686). The other limitation of the DLW method is that other parameters such as the duration, intensity, and frequency of moderate-to-vigorous PA or sedentary behaviour patterns cannot be evaluated using this technique (Coulston *et al.*, 2008:88).

Direct calorimetry involves the assessment of energy expenditure by measurement of heat production or heat loss directly during glycolysis, while ***indirect calorimetry*** measures the metabolic rate by determining the oxygen consumption (O_2) and the production of CO_2 from metabolism (Ainslie *et al.*, 2003:687). The direct method is difficult to use due to the technical

challenge of measuring the smallest amount of heat (Speakman, 2013:2). The indirect calorimetry is a more commonly used method because it is easier to operate, more portable and affordable (Hills *et al.*, 2014:3).

Direct observation is a more practical method of measuring PA especially among children (Sirard & Pate, 2001:450; Sallis, 2010:404). The direct observation method provides adequate quantitative and qualitative data on the PA of an individual and provides detailed information about the person's physical behaviour (e.g. behavioural cues, or the influence of environmental conditions). Other aspects of PA such as frequency, intensity, duration and type of activity, can be assessed (Sallis, 2010:408). The disadvantage of the direct observation method is that data collection is labour intensive and time-consuming and is thus not feasible for large populations.

The ***heart rate*** monitor can be used to assess the energy expenditure and the level of PA as it relies on the well-established linear relationship between heart rate (HR), oxygen consumption (VO_2) and energy consumption (Rennie *et al.*, 2001:939; Achten & Jeukendrup, 2003:517; Wicks *et al.*, 2011:2005; Hills *et al.*, 2014:5). The HR monitor can determine PA parameters such as duration and intensity of exercise and is cost-effective when using small sample sizes (Sirard & Pate, 2001:444; Keytel *et al.*, 2005:289). However, the use of HR monitors for the assessment of PA is restricted in many ways (Rowlands & Eston, 2007:271), for example, psychological and environmental stresses, hydration level, level of fitness, caffeine and some medications can significantly alter HR resulting in inaccurate data (Sirard & Pate, 2001:443; Rowlands & Eston, 2007:271).

Pedometers are electronic devices with motion sensors which are used to estimate distance walked or step counts over a period of time (Tudor-Locke *et al.*, 2002:2045). The correlation between pedometer step counts and VO_2 measured by a treadmill locomotion was (in a very early study) reported to be between $r = 0.62$ and 0.93 (Eston *et al.*, 1998:365). Pedometers are relatively cost-effective, reusable, objective and non-reactive, however, they can only measure total counts or steps over the observational period and cannot assess the intensity or pattern of activities performed (Sirard & Pate, 2001:445). The other limitation of pedometry is that it cannot measure the energy expenditure from cycling activities, carrying objects or running uphill (Armstrong & Welsman, 2006:1079).

Accelerometers are more advanced electronic devices with motion sensors that measure the accelerations and decelerations produced by body movement. They are suitable for use both in children and in adults (Rowlands & Eston, 2007:272) and provide a more accurate measurement of intermittent PA of both low and high intensity (Eston *et al.*, 2006:753; Armstrong & Welsman, 2006:1081). Accelerometers are non-reactive and reusable, however, they cannot measure

cycling activities and movement at a gradient as well as those activities that involve limited upper body movement (Sirard & Pate, 2001:447).

2.4 METABOLIC RISK FACTORS IN CHILDREN AND ADOLESCENTS

Metabolic risk factors are those factors that lead to the development of chronic diseases such as coronary heart diseases, stroke, CVDs and type two diabetes mellitus (DM) (Ekelund *et al.*, 2006:2450; Bankoski *et al.*, 2011:498). The most popular metabolic risk factors are abdominal (central) obesity, HBP, raised serum triglycerides, reduced serum cholesterol, and raised fasting plasma glucose (Ekelund *et al.*, 2006:2450; Moreira *et al.*, 2011:1). A cluster of three or more of these risk factors is known as metabolic syndrome (MetS) (Barrett *et al.*, 2014:1; Bankoski *et al.*, 2011:498).

The International Diabetes Federation defines MetS as having central obesity (as determined by waist circumference (WC) with ethnicity-specific values), and any two of the following risk factors: namely, raised serum triglycerides (>150 mg/dL (1.7 mmol/L), reduced serum high-density lipoprotein (HDL) cholesterol (< 40 mg/dL (1.03 mmol/L) in males; < 50 mg/dL (1.29 mmol/L) in females), raised BP (systolic BP > 130 mmHg or diastolic BP > 85 mmHg) and raised fasting plasma glucose >100 mg/dL (5.8 mmol/L), (Alberti *et al.*, 2006:476; Ntyintyane *et al.*, 2007:6). Among South Africans, a combined prevalence rate of MetS between 55.4–62% was reported among children and adolescents from Cape Town (Erasmus *et al.*, 2012:841). Furthermore, Sekokotla *et al.* (2017:134) reported a higher prevalence of risk factors for the MetS of 40.2% among female adolescents compared to their male counterparts from Mthatha in the Eastern Cape Province. Among adults, the prevalence was found to be high in women (25%) compared to men (10.5%) (Motala *et al.*, 2011:1032).

2.4.1 Overweight and obesity

Obesity is a medical condition characterised by the accumulation of excess body fat to the extent that it results in an adverse effect on health (Roussouw *et al.*, 2012:1; Aras *et al.*, 2015:414). Obesity can be categorised as abdominal (central or android) and peripheral (gynoid) obesity. In abdominal obesity, BF occupies the abdominal region of the individual whereas, in the peripheral type, BF is accumulated around the hip and thigh region (Aras *et al.*, 2015:414). Abdominal obesity plays an important role in the development of metabolic disorders and in the assessment of cardiovascular risk compared to peripheral obesity (Janghorbani *et al.*, 2012:376). Després (2012:1302) noted that individuals who are centrally obese have a higher prevalence of chronic diseases related to obesity such as CVDs, hypertension, type two DM, MetS and heart disease.

The most commonly used anthropometric index to measure obesity is BMI (Després, 2012:1301). In the early 1980s, it was evidently established that the ratio of waist-to-hip regional fat distribution (WHR), is a more accurate measure of obesity and is more strongly correlated to metabolic

complications and to cardiovascular outcomes than BMI (Kissebah *et al.*, 1982:254; Larsson *et al.*, 1984:1401). Later studies reported that measures of abdominal obesity, primarily WC (Ardern *et al.*, 2003:138) and more recently waist to hight ratio (WHtR), are more closely related to CVD morbidity and mortality than is BMI and WHR (De Onis & Lobstein, 2010:459; WHO, 2011). Studies revealing that excess abdominal fat is associated with hyperlipidaemia, CVD risk factors, type two DM, and other morbidities abound (Lurbe *et al.*, 2001:365; Janghorbani *et al.*, 2012:376; Aye & Sazali, 2012:546).

Precise measurement techniques of abdominal fat content involve the use of radiological imaging techniques which are quite expensive (Després, 2012:1304; Nuttall, 2015:121). In this regard, WC is often used as an alternative indicator of abdominal FM, because WC correlates with abdominal FM (subcutaneous and intra-abdominal) (Després, 2012:1304; Nuttall, 2015:121; Manish *et al.*, 2016:69). Individuals with a WC greater than 102 cm and 88 cm for men and for women respectively are considered to be at increased risk for cardiometabolic disease (Wang *et al.*, 2005:555). The WHtR index of an individual is defined as one's WC (centimeters [cm]), divided by the height (cm), and a WHtR >0.50 is used to determine abdominal obesity (Ashwell & Hsieh, 2005:303). The WHtR anthropometric index has been widely used in research to evaluate abdominal obesity among children (McCarthy & Ashwell, 2006:989; Sung *et al.*, 2008:2), and is a predictor of CVD risk factors in children and adolescents (Meininger *et al.*, 2010:119; Campagnolo *et al.*, 2011:265).

It was reported that the global number of overweight or obese young children below the age of five years increased from 32 million to 42 million over two decades (1990–2013), and in Africa alone the number increased from four to nine million during the same period (WHO, 2014). The World Health Assembly in 2014 warned that if current trends are not controlled, more than 70 million young children will be overweight or obese by the year 2025 globally.

Incidents of overweight and obesity in South Africa have been reported among children and adolescents who reside in both rural and urban areas (Puoane *et al.*, 2002:1041; Mantsena *et al.*, 2003:225; Monyeki *et al.*, 2005:877; Zeelie *et al.*, 2010:285; Kimani-Murage *et al.*, 2010:1; Toriola & Monyeki, 2012:796; Micklesfield *et al.*, 2014:14; Moselakgomo *et al.*, 2014:343; Pedro *et al.*, 2014:194; Pienaar, 2015:2; Moselakgomo *et al.*, 2015:730). Crude results from these studies showed that the prevalence of obesity among this population is on the rise and South African children and adolescents are gradually being exposed to the epidemic of chronic diseases.

2.4.2 Cardiovascular diseases (CVD)

CVD is defined as any disease that affects the cardiovascular system, principally cardiac diseases, vascular diseases of the brain and kidneys, and peripheral arterial diseases (Ginsberg, 2013:1). These conditions can cause narrowing or blocking of blood vessels and can lead to heart failure, ischaemic or coronary heart disease, heart attack, angina (chest pain) or stroke. CVD is known to be associated with

old age, however, antecedents of the disease such as obesity, hypertension, DM, physical inactivity, smoking, and atherosclerosis manifest at childhood stage (Maredza *et al.*, 2011:49). CVD is preventable in many cases through lifestyle modifications such as PA and dietary regulation, and can be detected early through regular screening examinations (Gyula, 2013); hence, it is important to adopt intervention strategies at an early stage (Maredza *et al.*, 2011:52).

In South Africa, the increase in CVD risk has been attributed to urbanisation, industrialisation and a Westernised lifestyle (Li, 2013:70). The South African national mortality statistics showed that CVD, respiratory diseases and cancer were responsible for 12% of the overall disease burden (Van Zyl *et al.*, 2010:72). Sadly, more than half of the deaths caused by these chronic diseases occur before the age of 65 years (Steyn & Fourie, 2007:2). It is projected that premature deaths due to CVD in people of working age (35–64 years) are expected to increase by 41% by 2030 (Steyn *et al.*, 2006:254).

2.4.3 Hypertension/High blood pressure (HBP)

Hypertension (or HBP) was previously known to be a condition for the aged population and urban dwellers, but nowadays is becoming increasingly prevalent in children and adolescents as well as among rural dwellers. HBP is a chronic disease, which manifests with elevated BP in the arteries (BeLue *et al.*, 2009:13).

Worldwide, hypertension is an important and modifiable risk factor for CVD and stroke (Danaei *et al.*, 2011:568; Dishman *et al.*, 2013:146) as well as premature mortality (WHO, 2009; Dong *et al.*, 2013:437), accounting for more than seven million deaths each year (Dong *et al.*, 2013:437). A possible reason for a high death rate may be due to the delay in clear symptoms and therefore this can be sometimes be missed (ACSM, 2017). The presence of HBP increases the risk of other chronic heart illnesses, such as ischaemic heart disease, heart failure, aortic aneurysms and atherosclerosis (Dionne *et al.*, 2012:18). Adolescents with elevated BP are at high risk of developing hypertension in adulthood (Ejike *et al.*, 2008:1; Benmohammed *et al.*, 2011:291; Franks *et al.*, 2010:485; Goon *et al.*, 2013:490). For example, Benmohammed *et al.* (2011:295) found that an estimated 50% of United States (US) children aged ten years living with BP levels above the 95th percentile become hypertensive by the age of 20 years.

Two measurements characterise BP, namely, SBP and DBP. SBP is the pressure/force of the blood when cardiac muscles are contracting, while DBP is the force when cardiac muscles relax. When interpreting BP readings, the systolic value is the top reading and the diastolic is the bottom reading. A resting BP range of 100–140 mmHg (systolic) and 60–90 mmHg (diastolic) is considered normal and healthy. If the BP persistently increases to values of, or above 140/90 mmHg (for adults), HBP is presumed to exist (BeLue *et al.*, 2009:13; Egbujie *et al.*, 2016:900; Mangena *et al.*, 2016:37).

Additionally, ACSM update of 2017, describe the BP cut-off for adults as follow; Normal: <120/<80 mm Hg, Elevated: 120-129/<80 mm Hg, Stage 1 hypertension: SBP between 130-139 or DBP between 80-89 mm Hg and Stage 2 hypertension: SBP ≥140 or DBP ≥90 mm Hg (ACSM, 2017). In children and adolescents, HBP is defined as persistent SBP and/or DBP of at least 95th percentile for sex, age and height measured on at least three separate occasions (Kagura *et al.*, 2015:2; Lurbe *et al.*, 2016:168). Children with an average SBP and/or DBP at least 90th but less than 95th percentiles are classified as having high normal BP (Lurbe *et al.*, 2016:168). Above these estimated cut-off levels of BP, it is assumed that the risk of morbid events will start to rise (Falkner, 2010:1219). The cut-off points and classification of BP are illustrated in Table 2-1 below.

Table 2-1 Definitions and classification of office BP (mmHg)

Stage	Systolic BP (mmHg)	Diastolic BP (mmHg)
Normal	< 120	< 80
Optimal	120–129	80–84
High normal	130–139	85–89
Grade 1	140–159	90–99
Grade 2	160–179	100–109
Grade 3	≥ 180	≥ 110
Isolated systolic	≥ 140	< 90

Seedat *et al.* (2014:288). South African hypertension practice guideline. 2014.

In South Africa, a prevalence of elevated BP has been reported among children and adolescents (Monyeki *et al.*, 2005a:116; Moselakgomo *et al.*, 2012:565; Goon *et al.*, 2013:490; Kagura *et al.*, 2015:1; Awotidebe *et al.*, 2015:3). Findings from these studies proved that the risk of HBP is gradually increasing across ages and gender, both in rural areas (Monyeki *et al.*, 2005a:116; Moselakgomo *et al.* 2012:565; Goon *et al.*, 2013:490; Pedro *et al.*, 2014:194) and urban areas (Kagura *et al.*, 2015:1; Kagura *et al.*, 2016:1123; Mangena *et al.*, 2016:38). High BP prevalence rate at adolescence and early adulthood (15–24 years) were reported to have doubled in a decade (2001–2010) (Mangena *et al.*, 2016:37). In one of the longest studies on South African children (The-Birth-To-Twenty-Study), Kagura *et al.* (2015:5) noted that the prevalence of HBP increases as children proceed through their teens into adulthood; they reported that at five years, 36.1% of children in the Soweto area had elevated BP and the number increased to 56.3%, between the ages of 13 and 18. A high prevalence of hypertension (21.2%) was also reported among adolescents from peri-urban areas of the Eastern Cape (Nkeh-Chungag *et al.*, 2015:59), while that of adolescents in Johannesburg town was found to be 14.8% (Kagura *et al.*, 2015:3). Further, among the adolescents from both low and high socioeconomic status in the Tlokwe municipality in Potchefstroom, a prevalence rate of 8.7% prehypertension and 4.3% hypertension was reported (Awotidebe *et al.*, 2015:3). Given the fact that childhood BP levels are predictive of later adulthood hypertension, the increase in the incidence of elevated BP among South African children and adolescents could result in an explosion of chronic diseases associated with HBP in the next decades to come if the situation remains unabated.

2.4.4 Dyslipidaemia

Dyslipidaemia, also known as high serum cholesterol, is the presence of elevated plasma cholesterol or triglycerides (TG), or a low level of HDL that contributes to the development of atherosclerosis (Kontush & Chapman, 2006:144) and ischaemic heart disease (Norman *et al.*, 2007:708). Cholesterol, TG, and HDLs are important constituents of the lipid fraction of the human body (Cox & García-

Palmieri, 1990:153). Cholesterol is important for the normal functioning of all body cells and is also a precursor of various critical elements such as adrenal, gonadal steroid hormones and bile acids (Cox & García-Palmieri, 1990:153). Plasma lipoproteins are classified into five major classes, namely: chylomicrons, very low-density lipoproteins (VLDL-C), intermediate-density lipoproteins (IDL-C), low-density lipoproteins (LDL-C), and high-density lipoproteins HDL-C (Cox & García-Palmieri, 1990:153). LDL-C is associated with an increased risk of atherosclerosis and coronary heart disease, while HDL-C is protective against the risks (Finn *et al.*, 2010:1282).

A TC concentration above 6.22 mmol/L (240 mg/dl) is defined as hypercholesterolaemia, and a TG concentration above 2.26 mmol/L (200 mg/dl) is defined as hypertriglyceridaemia. An LDL-C concentration above 4.14 mmol/L (160 mg/dl) is defined as high LDL-C. A concentration of HDL-C of less than 1.04 mmol/L (40 mg/dl) is defined as low HDL-C, while dyslipidaemia is defined as TG $\geq$ 2.26 mmol/l, or TC $\geq$ 6.22 mmol/l, or LDL-C $\geq$ 4.14 mmol/l, or HDL-C $<$ 1.04 mmol/l, or if someone is taking lipid-lowering drugs (Li *et al.,* 2016:2).

Globally, raised cholesterol is estimated to cause 2.6 million deaths (4.5% of total deaths per year) while a third of the global ischaemic heart disease is attributable to high cholesterol levels (WHO, 2014). The available 2014 regional statistics indicate that the highest prevalence of elevated TC was in the European region (54% for both sexes), followed by the American region (48% for both sexes). The African and South East Asian regions had the lowest percentages (22.6% and 29.0%) respectively (WHO, 2014).

From a meta-analysis study in South Africa by Vorster (2002:239-243), it was revealed that black men and women had the lowest levels of total serum cholesterol levels (4.20 mmol/L and 4.70 mmol/L respectively), while white men (6.39 mmol/L) and women (6.62 mmol/L) had the highest levels compared to other races. A high prevalence of elevated cholesterol levels was noted among urban dwellers compared to rural and farm dwellers (Vorster *et al.,* 2007:283; Pisa *et al.*, 2012:374; SANHANES-1, 2013:86). The incidence of elevated (non-fasting) blood cholesterol level was reported at 11% and 15% of males and females respectively in the township of Soweto in the Gauteng Province (Tibazarwa *et al.,* 2009:236). A recent study by Pedro *et al.* (2016:194) also reported the presence of low HDL-C concentrations of less than 1 mmol/l among boys and girls (7–15 years) from the Mpumalanga Province, which is an indicator of cardiometabolic risk among this group.

2.4.5 Hyperglycaemia

Hyperglycaemia is known as raised blood sugar which can lead to serious damage to many of the body's systems, especially the nerves and blood vessels (BeLue *et al.*, 2009:13). It is a chronic or acute increase in fasting or postprandial blood glucose concentration above the normal levels (Watson, 2010:215).

Hyperglycaemia occurs as a result of uncontrolled DM or decreased transportation and uptake of glucose into the muscle and adipose tissue as well as an increase in hepatic glucose output (Watson, 2010:215). A fasting plasma glucose level of 110–125 mg/dl indicates impaired glucose tolerance (IGT), and values greater than 126 mg/dl) indicate DM (American Diabetes Association, 2015:10).

Vorster *et al.* (2007:283) found that fasting serum glucose levels were lower (4.2 mmol/L) among South Africans who reside in urban areas of the North West Province compared to those who reside in rural areas (5.0 mmol/L). Contrastingly in the same province, Malan *et al.* (2008:325) found that people who live in towns had a slightly higher fasting serum glucose level of 4.74 mmol/L compared to 4.71 mmol/L for those from rural areas. Among all the provinces in South Africa, the Western Cape, Eastern Cape, Northern Cape, and North West Province were found to have the highest prevalence of high blood sugar measurements of greater than 6% SANHANES-1 (2013:98).

2.5 ROLE OF PHYSICAL ACTIVITY IN THE PREVENTION OF NCDs

Sedentary behaviour is one of the top five important risk factors for NCDs (2003:319; Masterson-Creber *et al.*, 2010:1). Despite the fact that the risks of a sedentary lifestyle and health benefits of regular PA are well known, many people across the world prefer a sedentary lifestyle. Results from cross-sectional studies (Macera & Powell, 2001:637; Dietz & Gortmaker, 2001:338) and longitudinal studies (Di Pietri *et al.*, 2004:1545; Must & Tybor, 2005:84; Brodersen *et al.*, 2007:141; Mitchell *et al.*, 2009:1; Toriola & Monyeki, 2012:796; Brook *et al.*, 2014:5) found that individuals who decreased their daily PA level showed a considerable increase in body weight, compared to those who maintained the same level of PA ($P < 0.001$). Regular PA and maintaining normal weight were also found to prevent or delay the onset of type two DM (CDC, 2009) predominantly by increasing insulin sensitivity, improving glucose uptake and utilisation from the blood to the skeletal muscles, as well as reducing the accumulation of visceral fat and TG (Laaksonen *et al.*, 2002:1612).

Studies that examined the role of PA in lowering the prevalence of risk factors for breast and colon cancer consensually agreed that PA intervention is important in the prevention of breast and colon cancer (Warburton *et al.*, 2006:801; Friedenreich & Cust, 2008:641; CDC, 2009; Wolin *et al.*, 2009:613). It is suggested that PA can reduce the level of the oestrogen hormone, which is thought to accelerate the development of breast and cervical cancer among women (World Cancer Research Fund, 2007:10; Suba, 2013:158). Engaging in regular PA has also been found to cause regular bowel movements which reduce the amount of time that the inside lining of the colon is in contact with toxic cancer-causing substances in undigested foods or alcohol (Bianchini *et al.*, 2002:5).

There is a consensus among research studies on the importance of regular PA in the protection against coronary heart diseases (Sesso *et al.*, 2000:975; Paffenbarger *et al.*, 2001:1184; Andrade &

Ignaszewski, 2007:540; Dishman *et al.*, 2013:147). Increasing regular PA level is beneficial in the prevention and treatment of coronary heart disease but the mechanism underlying the effectiveness of PA in preventing or treating CHD has not been established (Thompson *et al.*, 2003:3114). However, it can be attributed to the positive effects of PA in lowering the risk factors of CHD such as lipid, cholesterol, hypertension, and DM (Mora *et al.*, 2007:2110). The mid-twentieth-century studies by London-based researchers revealed the protective effects of PA against CHD among conductors of double-decker buses in London. It was reported that bus conductors were at low risk of CHD mortality because they were actively going up and down the decks in the bus compared to the drivers who spent most of the day seated (Paffenbarger *et al.*, 2001:1185). Postmen who cycled and walked to deliver the mail were also found to be more protected against CHD compared to other less active government executives and clerks who spent most of their time in sedentary work (Paffenbarger *et al.*, 2001:1186).

2.6 PHYSICAL ACTIVITY RECOMMENDATIONS

Researchers, governments and non-governmental organisations have devised PA guidelines and recommendation aimed at improving the quality of life among their citizens. Di Pietri *et al.* (2004:1545) recommended that individuals should engage in daily PA at a metabolic rate of at least 60% above the resting metabolic rate – equivalent to 45–60 minutes of brisk walking, gardening or cycling – in order to have a better quality of life. In addition, the WHO (2010) recommended that people should accrue at least one hour per day of MVPA for at least three days a week. The US federal government recommended that engaging in at least 30–60 minutes per day of MVPA could help to reduce the risk of developing colon cancer, primarily by reducing the prevalence of insulin resistance and hyperinsulinaemia, decreased intestinal transit time as well as decreasing higher vitamin D levels (Wolin *et al.*, 2009:611). Tudor-Locke *et al.* (2011:3) suggested that a daily step count of between 10,000 and 12,500 steps is beneficial in improving the quality of life for adults. The United Kingdom national obesity forum indicated that taking 3,000–6,000 steps daily is considered sedentary behaviour, 7,000–10,000 steps are moderately active, and 11,000 or more steps per day are very active (Tudor-Locke *et al.*, 2011:2). The Canadian Society for Exercise Physiology (2011) proposed that children and adolescents between aged 5–17 years should accrue at least 60 minutes of moderate-to-vigorous-intensity PA daily and this should include vigorous-intensity activities for at least three days per week, as well as activities that strengthen muscle and bone at least three days per week. In addition to this, Tremblay *et al.* (2011:62) suggested that children and adolescents should minimise recreational screen time (TV watching time, computer use, playing video games, etc.), motorised transportation, indoor time and extended sitting in the context of family, school and community activities. Despite these recommendations, many children and adults still live a sedentary lifestyle exposing themselves to the risks of CVDs.

A limitation with these studies on PA recommendations is that they only indicate PA recommended time (60 minutes daily for at least three days/week) but they are silent on the minimum or maximum time that an individual should spend in sedentary behaviour. Setting a limit to sedentary time may help to regulate the individual's sedentary habits and make the PA recommendation a complete set of the guideline. In most studies, TV watching time has been used as an index for measuring sedentary behaviour, hence sedentary limits (three hours/day) were only documented with reference to TV watching time and not for other forms of sedentary activities.

2.7 DETERMINANTS OF PHYSICAL ACTIVITY PARTICIPATION IN CHILDHOOD AND ADOLESCENCE

Participation in PA may be affected by many perceived barriers. A study by Reichert *et al.* (2007:516) revealed that among the men and women who participated in the study, 85.1% had reported having at least one barrier to PA. Many factors have been identified that determine PA participation in childhood and adolescence stages including personal and environmental factors. Existence or non-existence of these factors can positively or negatively influence participation in PA and they vary demographically from place to place (Reichert *et al.*, 2007515; Dishman *et al.*, 2013:508).

Personal factors: Personal factors include such variables as lack of time for PA (Reichert *et al.*, 2007:515), lack of interest in PA (Motl *et al.*, 2001:115; Reddy *et al.*, 2003:63; Graham *et al.*, 2014:605) and individuals' negative attitude towards PA (Grieser *et al.*, 2006:45; Toriola & Monyeki, 2012:805). **The environmental factors** that affect engagement in PA among youths include availability of facilities and equipment (Mehmeti, 2015:123), accessibility of the facility in terms of distance from residential area to the facility (Dishman *et al.* 2013:517), as well as safety and security of the neighbourhood (Brady & Kahn, 2002:24; Beenackers *et al.*, 2011:4; Oyeyemi *et al.*, 2012:6)

Among South African children and adolescents, lack of interest, lack of facilities, unsuitable sporting facilities/clubs in the area of residence, insufficient access to facilities, lack of transport after school, facilities located too far from place of residence, as well as high crime rate are among the commonly reported barriers to participation in PA and sport (Reddy *et al.*, 2003:63; Shirinde *et al.*, 2012:232; Kubayi *et al.*, 2013:339; van den Berg *et al.*, 2014:910). Most public schools in South Africa were constructed without playing facilities (Reddy *et al.*, 2003:63), meaning that many children have little opportunity to engage in play activities in between lessons at school. Besides the lack of facilities to participate in PA, the decline in PA among South African children has also been blamed on the increased reliance on non-active transportation modes, increased automation of daily living activities, and increased TV watching time and other screen-related technologies (Rosiek *et al.*, 2015:9411).

2.8 RELATIONSHIP BETWEEN CHANGES IN BODY COMPOSITION, PHYSICAL ACTIVITY, AND TV WATCHING

TV watching is one of the modifiable lifestyle behaviours that is linked with lower TEE and fatness among children and adolescents (Reilly *et al.,* 2005:5; Eisenman *et al.,* 2008:613; Rivera *et al.,* 2010:160). The mechanisms in which TV watching is involved in the aetiology of obesity are that prolonged TV watching time reduces energy expenditure (primarily by decreasing the time spent on PA), lowers resting metabolic rate and increases energy intake (due to snacking while watching TV and exposure to advertisements of energy-dense foods on TV), all of which in turn contribute to overweight and obesity (Robinson, 2001:1017; Rosiek *et al.,* 2015:9411; Kelly *et al.,* 2015:159).

The association between PA and TV watching time in relation to changes in body composition variables has been studied mainly among children and adolescents from developed countries (Proctor *et al.,* 2003:827–833; Marshall *et al.,* 2004:1238-1246; Heelan & Eisenmann, 2006:200–209; Rivera *et al.,* 2010:159–65). There is limited information on the longitudinal interrelationship between these variables in children and adolescents from developing countries (Gomez *et al.,* 2007:2). There is a paucity of studies that explore these inter-relationships among South African children and adolescents. Although a decline in PA and the increased prevalence of overweight and obesity have been reported among South African children and adolescents (Reddy *et al.,* 2003:64; Monyeki *et al.,* 2005:877; Roussouw *et al.,* 2012:1 Micklesfield *et al.,* 2014:14; Toriola & Monyeki, 2012:796; Reddy *et al.,* 2012:262; Pienaar, 2015:2), their long-term interaction with TV watching time among this population has not been investigated. A cross-sectional study by McVeigh *et al.* (2004:987) found that children from low socio-economic status families who spent the lowest amount of time watching TV had a high level of PA, and low body weight, BMI and fat mass. Monyeki *et al.* (2012a:75) reported a significant positive relationship between body mass and TV watching time (r = 0.56; p = 0.05) among the overweight group of 14-year old adolescent boys and girls in Potchefstroom, while a strong significant positive relationship was observed between percentage BF and TV watching time in the obese group (r = 0.94; p = 0.01). Nationally representative data on time spent watching TV and being physically active among South African adolescents are available (Draper *et al.,* 2014:100; Uys *et al.,* 2016:268). However, longitudinal studies that have investigated the combined influence of PA and TV watching time on body composition have not been found among South African children and adolescents who live in the Tlokwe municipality in Potchefstroom.

A growing body of evidence from both cross-sectional and longitudinal studies supports the existence of an interaction of PA and TV watching time with overweight and obesity (Must & Tybor, 2005:85; Heelan & Eisenmann, 2006:203; Gomez *et al.,* 2007:2; Herrick *et al.,* 2014:4). Several studies (Dietz & Gortmaker, 1985:808; Proctor *et al.,* 2003:830; Hancox *et al.,* 2004:260; Roseik *et al.,* 2015:9408; Liao *et al.,* 2013:588; Staiano *et al.,* 2013:40), but not all (Robinson *et al.,* 1993:273; Durant *et al.,*

1994:449; Katzmarzyk *et al.,* 1998:321) agreed that PA is lower during TV watching time and low levels of PA combined with prolonged TV watching time among children is linked with an increase in the indices of overweight and obesity.

Cross-sectional data from a long study (Iowa Bone Development Study) revealed that vigorous PA and TV watching time were consistently and highly associated with adiposity among four to sixyear old children in the US. Children who were in the lowest quartile for vigorous PA had an average%BF that was 4% higher than those children in the highest quartile for vigorous activity while the %BF for children who were in the highest quartile for TV watching time were on average 3% greater than those children who watched TV the least amount of time **(**Janz *et al.*, 2002:568).

Further, The Framingham Children's study reported a longitudinal link between low activity levels and long hours of TV watching and increased gains in the sum of SKF in later life (Proctor *et al.*, 2003:830). In another longitudinal study, Hancox *et al.* (2004:258) found that prolonged TV watching time during childhood and adolescence was associated with higher BMI ($p = 0.007$), poor cardiorespiratory fitness ($p = 0.001$), and raised serum cholesterol ($p = 0.05$) during early adulthood. Although these relationships have been widely and scientifically confirmed through research, changes in body fatness, especially among children, may be explained by other factors such as nutrition, diet, and genetics other than TV watching or PA alone. Marshall *et al.* (2004:1242) suggested that the relationship between sedentary behaviour and health indices is unlikely to be explained using single markers of inactivity such as TV watching time or video/computer game use. Rosiek *et al.* (2015:9411) particularly singled out the over-consumption of high-calorie diets and snacks of little nutritional value (low in protein, vitamins or minerals) as other important contributors to childhood obesity.

Due to the increasingly reported link between sedentary behaviour (particularly TV watching) and low PA and the risks in relation to obesity, intervention methods to regulate TV watching time among children and adolescents have become a priority. Some of the early studies in the United States of America (USA) (Dietz & Gortmaker, 1985:807; Tucker & Friedman, 1989:516) found that people who watched TV more than three hours per day had a high risk of developing obesity compared to those who watched for less than three hours daily. Later research studies have provided some related evidence on the relationship between TV watching time and risks of obesity among children and adolescents, for instance in the US (Mendoza *et al.,* 2007:1; Melkevik *et al.* 2015:5) and Finland (Tammelin, 2009:284) reported that children who sat in front of the TV for more than two hours per day had a higher risk of being overweight or obese.

Contrary to these research findings have been reported though (Tuckers, 1986:797; Durant *et al.*, 1994:449; Katzmarzyk *et al.,* 1998:321). In the studies by Tuckers (1986) and Durant *et al.* (1994), TV

watching time was found to be weakly and negatively correlated with physical activity. Durant *et al.* (1994) did not find an association between TV watching time with any of the measures of body composition (sum of skinfolds, WHR and BMI). A longitudinal study in California (Robinson *et al.*, 1993:277) reported that the time spent watching TV by sixth and seventh-grade girls was not associated with changes in adiposity (BMI, skinfolds thickness) and was weakly and inversely associated with PA. Grund *et al.* (2001:1245) suggest that the influence of TV watching time on PA and obesity is unclear at the childhood stage. Another study by Ekelund *et al.* (2006:2451) found no correlation between TV watching time and PA (r = 0.013, p=0.58), however, they found an association between TV time and obesity independent of PA, and both TV watching time and PA were separately related to adiposity. In another study, Tammelin *et al.* (2009:1067), found a negative association between TV watching time and self-reported PA among 15–16-year old Finnish adolescents. Of interest among these contrasting studies is that they evaluated PA and TV watching time using self-reports hence there is a chance that time spent on these activities was over-reported, leading to a lack of significant relationships between the variables.

Despite contrasting evidence on the relationship between PA, TV watching time and body composition changes, data from lifestyle studies has revealed that spending less time on PA accompanied by prolonged TV watching time and screen-related activities such as computer video games, is not only associated with weight disorders but is also linked to a high prevalence of several causes of mortality and morbidity including CVDs (Monyeki *et al.*, 2012a:75; Tremblay *et al.*, 2011:14). Controlling PA and TV watching time at childhood stage (through increasing MVPA and minimising time spent on TV) is beneficial in preventing overweight and obesity-related health problems later in life (Epstein *et al.*, 2000:223; Tammelin *et al.*, 2009:1071; Troiano *et al.*, 2008:184; Jago *et al.*, 2013:10).

2.9 RELATIONSHIP BETWEEN BODY COMPOSITION, PHYSICAL ACTIVITY, AND SELECTED METABOLIC RISK FACTORS

MetS is a constellation of coexisting metabolic risk factors, which include abdominally/centrally distributed obesity, lipid disorders, raised BP, impaired glucose intolerance and insulin resistance (Grundy *et al.*, 2004:433; Eckel *et al.*, 2005:1420; Moreira *et al.*, 2011:1; Janghorbani *et al.*, 2012:376; Nikolopoulou *et al.*, 2012:935; Després, 2012:1303; Wang *et al.*, 2012:914; Gierach *et al.*, 2014:2; Pedro *et al.*, 2014:194). Research has found that if these risk factors remain unabated at childhood and adolescence stage, they can gradually develop and affect individuals later in life (Srinivasan *et al.*, 2006:37; Robinson *et al.*, 2015:373).

There is a large body of consistent evidence, mostly from cross-sectional data, suggesting that increased total sedentary time objectively measured through accelerometry, is associated with high levels of cardiometabolic risk factors (Healy *et al.*, 2011:590; Celis-Morales *et al.*, 2012:1; Henson *et al.*, 2013:1012; Kim *et al.*, 2013:6; Cooper *et al.*, 2014:73; Chase *et al.*, 2014:108; Carson *et al.*, 2014:23;

Wijndaele *et al.,* 2014:305; Qi *et al.*, 2015:1560; Brocklebank *et al.,* 2015:96). Studies have indicated that individuals who are ranked as less active in childhood or adolescence are more likely to become inactive adults (Tremblay *et al.,* 2014:11; Goodman *et al.,* 2013:228) and have a high prevalence of developing multiple metabolic risk factors for CVDs (Pan & Pratt, 2008:279). This evidence suggests the importance of having a physically active lifestyle in childhood in order to benefit from the protective effect of PA from metabolic risk factors of CVDs.

The influence of PA on the metabolic risk factor of NCDs has been studied among children and adults from high-income countries (Srinivasan *et al.*, 2006:33; Rizzo 2008:50; Bailey *et al.,* 2012:1317; Park & Larson, 2014:499–507; Salonen *et al.,* 2015:1–12) and among low and medium income countries (Kim *et al.*, 2011:1–8; Fam *et al.*, 2013:1014; Barret *et al.*, 2014:1–7; Latt *et al.*, 2016:782–788). Few research studies have investigated the association between body composition and PA in relation to metabolic risk factors among adolescents in South Africa. Despite limited availability of studies on the relationships between body composition, PA and metabolic risk factors in children and adolescents, scarcity still exists on studies that address the longitudinal relationships between these variables among childhood and adolescent populations in the North West Province. An increasing prevalence of risk factors of metabolic illnesses and CVD has been reported among South African children from rural areas (Monyeki *et al.,* 2005b:59; Kimani-Murage *et al.,* 2010:1; Moselakgomo *et al.,* 2012:562; Mamabolo *et al.,* 2014:194) and in urban settings (Levitt *et al.,* 1999:946; Matsha *et al.*, 2009:363; Zeelie *et al.*, 2010a:147).

The major highlights of studies in this area are that the prevalence rate of metabolic-related diseases is on the rise, has reached unprecedented levels and become a health delivery threat for many governments around the world. A key finding from these studies is that obesity (particularly abdominal obesity) is the primary modifiable risk factor for metabolic illnesses and, most importantly, PA is a modifier of both adiposity and metabolic risk factors. Importantly, BF, which is subcutaneously distributed around the gluteofemoral region and lower abdomen, is highly associated with lower metabolic risk of overweight and obesity compared to that which is centrally distributed and in the upper abdomen (Grundy *et al.,* 2004:433; White & Tchoukalova, 2014:377). Other studies have affirmed the coexistence of abdominal obesity and other risk factors such as hypertension, DM, hypercholesterolaemia, hypertriglyceridaemia, insulin resistance and impaired glucose metabolism (Hossain *et al.*, 2007:213; Bouguerra *et al.* 2007:859; Grundy 2008:629; Rizzo *et al.*, 2008:586; Jung *et al.*, 2016:675; Awotidebe *et al.,* 2016:248). For example, data from a national diabetes screening study among children and adolescents (6–18 years) in Taiwan has shown that individuals who had type two DM also had high BMI, -cholesterol, and -BP (Wei *et al.*, 2003:1345). Therefore, intervention strategies to control metabolic-related diseases should predominantly address obesity and its related causes such as physical inactivity (PI), sedentary behaviour and dietary patterns, particularly among children and adolescents.

Epidemiological evidence suggests that high levels of PA and cardiorespiratory fitness are associated with a healthy metabolic risk profile among children and adults (Steele *et al.*, 2008:342; Salonen *et al.*, 2015:1). A plethora of studies in this area consensually agreed that regular MVPA can promote healthy body composition and reduce the prevalence of metabolic risk factors of many chronic diseases (Monyeki *et al.*, 2005:877; Warburton *et al.*, 2006:801; Steele *et al.*, 2008:342; Vogel *et al.*, 2009:303; Moreira *et al.*, 2011:2; Barret *et al.*, 2014:1). Cardiovascular fitness, which is a product of MVPA, and was also found to be inversely associated with a cluster of metabolic risk factors and the relationship was mediated by BF (Carrol & Dudfield, 2004:380; Rizzo, 2008:51). Similar evidence was reported in controlled studies (Kraus *et al.*, 2002:1483; Gutin *et al.*, 2005:746; Ruiz *et al.*, 2006:299; Dua *et al.*, 2014:89; Velásquez-Rodríguez *et al.*, 2014:1) and population studies (Torrance *et al.*, 2007:139; Metcalf *et al.*, 2009:470; Moselakgomo *et al.*, 2012:562; Dwivedi *et al.*, 2016:971). This interaction is observable at a younger age and can provide some future indications of metabolic-related disease patterns in adulthood (Rizzo, 2008:51).

Abdominal obesity is also associated with high morbidity and -mortality, as well as risk factors of coronary heart diseases like DM, hypertension and hyperlipidaemia (Yusuf *et al.*, 2004:937; Poirier *et al.*, 2006:906; Lenz *et al.*, 2009:646; Pedro *et al.*, 2016:194). Data from the EPIC-PANACEA study (Besson *et al.*, 2009:502) reported a strong inverse relationship between PA and body composition (measured by BMI) and abdominal obesity. An increase in PA level was found to play a protective role in both abdominal obesity as well as total obesity (Besson *et al.*, 2009:502; Martins *et al.*, 2015:106), while low BF mass and WC were reported among the regular physically active individuals compared to the inactive individuals (Moreira *et al.*, 2011:2; Staiano *et al.*, 2012:1011). Although it is well documented that PA has several health benefits, which include a healthy quality of life among children and adolescents, it is not clear at what intensity PA could be helpful in the reduction of metabolic risk factors. However, studies have found that a combination of low PA and high adiposity (BMI or %BF) increase the prevalence of metabolic risk factors and subsequently MetS and CVDs (Després & Lemieux, 2006:881; Bouguerra *et al.*, 2007:859; Roberts *et al.*, 2013:4; Shabestari *et al.*, 2013:1957).

Insulin resistance is another metabolic risk factor that was reportedly linked with low PA level and high adiposity and is a core feature of MetS (Reaven, 1988:1605; Landsberg, 2008:1607; Velásquez-Rodríguez *et al.*, 2014:6). Most of the studies which investigated the association between PA, BMI/%BF and insulin resistance (Ku *et al.*, 2000:506; Bunt *et al.*, 2003:2524; Ball *et al.*, 2004:77; Imperatore *et al.*, 2006:1567 Després *et al.*, 2008:1046) found that a high level of PA moderates body weight and insulin action. In an editorial, Landsberg (2008:1607) reiterated that central obesity is an important environmental cause of insulin resistance, together with other factors such as a sedentary lifestyle and a high fat intake. Increasing PA level is accompanied by a decrease of both markers of both adiposity and insulin resistance. On the other hand, adiposity was found to be positively associated with insulin resistance independent of PA level (Pischon *et al.*, 2003:1055; Brage *et al.*, 2004:1503;

Rizzo *et al.*, 2007:388; Velásquez-Rodríguez *et al.*, 2014:6). Individuals who are regularly active are at low risk of being overweight and having insulin resistance.

Available evidence on the interaction between PA, adiposity, and hypertension revealed that a low level of PA among overweight children and adolescents predisposes them to a premature development of HBP (Torrance *et al.*, 2007:140; Dua *et al.*, 2014:89). Compelling evidence is available from both cross-sectional and longitudinal studies on the existence of a strong positive relationship between BMI and HBP among children and adolescents (Weiss *et al.*, 2004:2368; Falkner *et al.*, 2006:197; Adediran *et al.*, 2008:1; Zhang & Wang, 2011:630; Moselakgomo *et al.*, 2012:562; Dua *et al.*, 2014:89; Kaguara *et al.*, 2016:1; Dwivedi *et al.*, 2016:971). Comparative cross-sectional studies have shown that overweight and obese children had significantly HBP compared to their lean counterparts (Nyberg *et al.*, 2011:244; Kelly *et al.*, 2015a:174; Dwivedi *et al.*, 2016:973). A series of tracking studies that used data from a longitudinal study (The Bogalusa Heart Study) on risk factors of CVDs among schoolgoing children which started in the early 1970s (Aristimuno *et al.*, 1984:895; Berenson, 2002:3–7; Freedman *et al.*, 2012:159–166) have convincingly reported that BP was significantly higher in children within the upper percentiles of BMI compared to those in the lower percentiles. A meta-review of intervention studies on PA and BP among children revealed that an average time of at least 40 minutes of moderate-to-vigorous aerobic PA for at least three to five days per week is required to improve the vascular function and reduce the risk of HBP in obese children (Torrance *et al.*, 2007:139–149). For adults to maintain a healthy weight and a lower BP, the CDC (2014) recommended that they should accrue at least one hour of moderate-intensity exercise daily and the exercises should include at least a session of brisk walking or cycling within a week.

Other metabolic risks factors which include hypercholesterolaemia and hypertriglyceridaemia, as well as impaired glucose metabolism, were also found to be positively associated with time spent in sedentary behaviour such as television/computer activities ($P<0.01$), and inversely associated with moderate-to-vigorous leisure time PA ($p<0.05$) (Wijndaele *et al.*, 2009:424). This means that as the time spent on sedentary behaviour increases, the odds for hypercholesterolaemia, hypertriglyceridaemia, and impaired glucose metabolism also increase and conversely, decrease with an increase in PA level. Miller *et al.* (2011:2316) revealed that PA (particularly aerobic activity) improves lipid oxidation, thereby enhancing the breakdown and utilisation of triglycerides in skeletal muscles.

There is credible evidence from meta-analysis (Yates *et al.*, 2007:1117), cross-sectional studies (Wijndaele *et al.*, 2009:421; Salonen *et al.*, 2015:1; Tarp *et al.*, 2016:145) and longitudinal studies (Lindstrom *et al.*, 2003:3230; Ekelund *et al.*, 2007:337) indicating the contribution of PA to the prevention of impaired glucose metabolism and type two DM, independent of dietary change among obese and pre-diabetic individuals. For instance, a longitudinal study (Ekelund *et al.*, 2007:337), indicated that an increase in PA energy expenditure (PAEE) over a long period of time is accompanied

by improvements in glucose tolerance, insulin sensitivity and a reduction in the clustered metabolic risk score, independent of changes in adiposity. The primary outcome of randomised controlled trials (Oldroyd *et al.,* 2006: 117; Zeelie *et al.,* 2010a:147) was that the incidence of type two DM was significantly reduced in the intervention group compared to the control group. This suggests that PA has a protective and therapeutic effect on the incidence of DM, insulin resistance, and impaired glucose tolerance.

Few variations have been reported on the relationship of PA to other individual risk factors. For instance, Metcalf *et al.* (2009:470) did not find any clinically or statistically significant associations between PA and insulin resistance before or after controlling for both diet and %BF. Similarly, Nguyen *et al.* (2017:14) found that overweight or obese individuals with high PA and low sedentary levels had higher odds of type two DM compared to their counterparts with normal weight, low PA and high sitting time. They concluded that high BMI and not PA can attenuate the risk of type two DM. Despite these varying research findings, evidence from the majority of studies overwhelmingly confirmed that PA is inversely correlated with body composition variables such as BMI and %BF, as well as selected metabolic risk factors. Regular PA contributes to a reduction in obesity and clustering of metabolic risk factors. Early detection of these risk profiles is very important and allows quick identification of children who may be predisposed to the risk of CVD (Siren *et al.*, 2012:1; Bailey *et al.*, 2015:1148).

2.10 CHAPTER SUMMARY

Incidents of PI among children and adolescents across the world have been reportedly on the rise. This increased prevalence has been found to contribute to the development of selected metabolic risk factors which have been known to be major causes of morbidity and mortality associated with CVD and other chronic metabolic diseases. Among all the metabolic risk factors, abdominal (central) obesity has been found to be closely associated with a high risk of chronic diseases and has also been noted to coexist with other metabolic risk factors such as hypertension, dyslipidaemia and insulin resistance. PI, poor diet, and nutritional habits have been identified as primary contributors to the incidence of obesity, although other factors like genetics and psychological factors have been found to play a role.

Several governments including the US, British, Finnish and Canadian governments and non-governmental bodies, such as WHO, the UK National Obesity Forum and the Canadian Society of Exercise Physiology, have made recommendations to promote PA and improve the quality of life among children, adolescents and adults. The WHO has recommended that individuals should engage in MVPA for at least 30 minutes per day, for at least three times a week, or take at least 10,000 step counts daily walking from one place to another (WHO, 2010), while the US Federal government recommended that children and adolescents should engage in at least 30–60 minutes per day of MVPA for at least three days per week. Despite these global recommendations, many people across the world remain physically inactive and prefer indoor sedentary leisure time activities at the expense of outdoor activity (Wolin *et*

al., 2009:611). Factors such as a general dislike of PA, lack of time to engage in it, lack of parental and peer support, unavailability of equipment and facilities for exercising, and distance from home to playing facilities, as well as safety and security fears, have been found to influence children and adolescents' participation in PA. TV watching time, computer video games playing and other screen-related activities have been reported as the main leisure time activities that have contributed to sedentary time among children and adolescents. Spending long hours TV watching has been found to be inversely associated to PA time and positively associated with the incidence of obesity while spending more on MVPA has been found to lower the prevalence of metabolic risk factors. Therefore, a multifactor approach that includes engaging in regular MVPA, reducing time spent TV watcing, and proper monitoring of dietary and nutritional behaviour, starting from childhood and adolescence may help to reduce the risk factors of metabolic-related illnesses.

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CHAPTER 3
TWO-YEAR CHANGES IN BODY COMPOSITION, PHYSICAL ACTIVITY AND SELECTED METABOLIC RISK FACTORS AMONG ADOLESCENTS LIVING IN THE NORTH WEST PROVINCE OF SOUTH AFRICA: THE PAHL STUDY

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Two-year changes in body composition, physical activity and selected metabolic risk factors among adolescents living in Tlokwe Municipality of the North West Province, South Africa: the PAHL study

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3.1 ABSTRACT

The increase in childhood obesity in low- to middle-income countries is linked to both individual and clustered metabolic risk factors. The purpose of this study was to determine the two-year changes in body composition, physical activity (PA) and selected metabolic risk factors (abdominal obesity and blood pressure (BP)) among 14- to 16-year old adolescents from the Tlokwe municipality in the North West Province of South Africa. A total of 289 adolescents (116 boys and 173 girls) aged 14 years participated in the study. Body composition was measured according to the International Standard of Advancement of Kinanthropometry (ISAK) standard procedures. PA level was measured using the International Physical Activity Questionnaire Short version (IPAQ-S). Abdominal obesity was determined using waist circumference (WC) measurements, and resting BP was determined by Omron MIT Elite Plus. Overweight gradually increased by 7.6% over the two-year period. The increase was higher among the girls (12.2%) compared to the boys (2.2%), ($p \leq 0.001$). Participation in low physical activity (LPA) increased by 8.2% for the whole group and moderate physical activity (MPA) gradually decreased (15.2%). With regard to the metabolic risk factors, boys had a significantly higher WC at every measurement point ($p \leq 0.001$) compared to girls. The percentage of adolescents in the prehypertensive/hypertensive category increased by 5% and the increase was greater in girls than boys ($p \leq 0.001$). In summary, adolescent girls were more overweight, obese and less physically active compared to the boys over a period of time and boys had a greater WC and SBP at every point of measurement compared to the girls.

Keywords: Obesity, Body composition, Physical activity, Metabolic risk factors, Adolescents

3.2 INTRODUCTION

Childhood obesity is one of the most serious public health challenges of the twenty-first century affecting many low- and middle-income countries, predominantly in urban settings (WHO, 2012). The World Health Organization (WHO) report noted that in 2012 nearly three-quarters of the non-communicable diseases (NCDs) deaths (28 million) occurred globally (WHO, 2012). In this report, it was stated that the leading cause of these deaths was cardiovascular diseases (CVDs) accounting for 46.2% of the deaths.

A global prevalence rate in childhood obesity of 47% was reported from 1980 to 2013 (Ng *et al.*, 2014) and the highest prevalence rate was reported in countries mostly from Africa, Latin America and Asia; that is those that are undergoing economic transition and whose health delivery systems are very weak (Hossain *et al.,* 2007; Monyeki & Kemper, 2008; Ellulu *et al.*, 2014). This worldwide prevalence of obesity has resulted in high morbidity and mortality rates; and has become an extra burden, especially on the African continent which is also under the threat of communicable and poverty-related diseases such as malaria, malnutrition, cholera and infant mortality (Adeboye *et al.*, 2012).

Obesity coexists with other metabolic abnormalities such as high BP, type two diabetes mellitus (DM) and insulin resistance (Eckel *et al.,* 2011), impaired glucose tolerance (Rivers *et al.,* 2014) and dyslipidaemia (Reuter *et al.,* 2016). These metabolic abnormalities are more closely associated with abdominal (central) obesity than peripheral obesity (Grundy *et al.,* 2004). Abdominal adiposity (determined by waist circumference [WC]) is an important metabolic risk factor of CVD (Després, 2012).

Although the aetiology of obesity remains multidimensional, it is assumed to be an outcome of several health risk factors such as physical inactivity (PI) and a sedentary lifestyle as well as uncontrolled nutritional habits during childhood and adolescence stages (Berenson, 2002). Sedentary behaviour, such as television (TV) watching and engaging in computer related activities during childhood, has contributed to the obesity epidemic and the rising prevalence of both individual and clustered metabolic risk factors (Ellulu *et al.,* 2014; Draper *et al.,* 2014). It is reported that increased low PA participation and sedentary behaviour at childhood stage is positively associated with a long-term increase in body mass index (BMI), percentage body fat (%BF) and a cluster of metabolic risk factors (high blood pressure (HBP), WC, high levels of low-density lipoprotein-cholesterol (LDL-C), triglyceride (TG) levels and fasting glucose) (Salonen *et al.*, 2015). On the other hand, regular participation in moderate-to-vigorous physical activity (MVPA) during childhood and adolescence is associated with favourable body composition and metabolic profiles later in life (Ekelund *et al.,* 2012; Bailey *et al.,* 2015). The risk of cardiometabolic-related mortality is lower among obese individuals with high physical activity (HPA) levels compared to normal weight individuals with LPA levels (Koolhaas *et al.,* 2017). These

results indicate the important role of PA in negating the risk of cardiometabolic-associated illnesses. Knowledge of the changes in body composition, PA, the development of obesity and other metabolic risk factors is essential because it can help to develop intervention strategies that can prevent or reverse the effects of obesity in children and adolescence. Such knowledge is also important in positively modifying childhood PA behaviour, nutritional habits and leisure time preferences (Moselakgomo *et al.*, 2015).

Studies have successively reported a gradual decline in PA and an increased prevalence of overweight and obesity and other metabolic risk factors of CVD among South African children (Toriola & Monyeki, 2012; Moselakgomo *et al.*, 2015). However, there is limited data on the longitudinal changes in body composition, PA and selected metabolic risk factors (abdominal obesity and BP) among adolescent learners from the Tlokwe Local Municipality of Potchefstroom. This longitudinal study may help to understand the long-term interaction of these variables and appropriate intervention strategies to prevent or reduce the prevalence of metabolic risks associated with unhealthy body composition and PI among the adolescent population. Thus, the purpose of this study is to determine longitudinal changes in body composition, PA and selected metabolic risk factors (abdominal obesity and BP) among adolescents living in the North West Province of South Africa.

3.3 METHODOLOGY

Design

The current study was part of the Physical Activity and Health Longitudinal Study (PAHLS, 2010–2014), whose main objective was to evaluate the development of PA and determinants of health risk factors among 14-year old high school students in Tlokwe municipality in the North West Province, South Africa, over a five-year span (Monyeki *et al.,* 2012). For the purpose of this study, both two-year cross-sectional and longitudinal data collected from 2011 to 2013 was utilised to determine the longitudinal changes in body composition, PA and selected metabolic risk factors (abdominal obesity and BP) among adolescence.

Participants

A total of 289 learners (116 boys and 173 girls) were selected from six out of eight schools. Of the six schools, two schools were from the Central Business District (CBD) comprised mostly of adolescents from the high socio-economic families and four schools were from the township areas comprising adolescents from low socio-economic families.

The selected learners' mean age were 14.9±0.76 years in 2011 (at baseline measurement), 15.6±0.77 years in 2012 and 16.4±0.78 years in 2013. School records as well as participants' birth clinic cards

were used to establish the age of the participants in the study. Dropout rates of 21% (2012) and 33% (2013) from the 2011 measurement point were observed. The observed dropout rate was due to participant absenteeism during the day of measurements, dropout from the school or transfer from one school to another. These reasons for dropout were beyond the study's control, hence participant attrition did not have a significant effect in the analyses of the objectives of the current study. Detailed information concerning the participants and methods of data collection have been published elsewhere (Monyeki *et al.*, 2012).

Measurement procedures

Before the commencement of data collection process, permission was granted by the District Manager of the Department of Basic Education in Potchefstroom, North West Province. Prior to the anthropometric measurements under the supervision of the principal investigator, the International Physical Activity Questionnaire Short version (IPAQS) was administered to the participants who were assembled in a classroom and adequate instructions were given. Participants completed the questionnaire independently, with no time limit set for completion. All anthropometric sites were measured twice according to standard procedures by Level 2 International Society for the Advancement of Kinanthropometry (ISAK)-certified anthropometrists.

Anthropometric and body composition measurements

Height, body mass, skinfolds thickness (triceps and subscapular skinfolds), and WC and hip circumferences were measured using the standard procedures described by ISAK (Marfell-Jones *et al.*, 2006). Waist-to-height ratio (WHtR) was calculated as waist (in centimetre [cm])/height (cm). Body mass index (BMI) was calculated as body mass/stature^2 (kilogram (kg)/ meter (m)^2). Subsequently, age-specific BMI for children was used to determine the following categories: overweight, normal weight and underweight, respectively (Cole *et al.*, 2007). Percentage BF was calculated from subscapular and triceps skinfolds (milimeters [mm]) measurements using Slaughter *et al.*'s equation (1988).

Measurement of physical activity (PA)

PA was assessed using the short form of the IPAQ (WHO, 2009). IPAQ is considered suitable for use by adolescents at different settings (WHO, 2002) and its short form consists of seven items which identify the frequency and time spent on walking and engaging in other MVPA during the seven days prior to questionnaire administration. In the IPAQ only those sessions that lasted ten minutes or more were analysed and various types of PA related to transportation, household chores and leisure time activity were included. IPAQ also elicits information about time spent sitting, which is used as an indicator of inactivity. PA was classified into three categories namely: Low activity (metabolic equivalent of task (METS)<3), moderate activity (METS 3–6), and high activity (>6) according to the 2005 guidelines for data processing and analysis of the IPAQ. Total physical activity (TPA) was calculated from all PA components performed within seven days of a week.

Metabolic risk factors

Abdominal obesity

Abdominal obesity was determined using WC measurements (Grundy *et al.,* 2004). WC was measured at the abdomen at its narrowest point between the lower costal (10^{th} rib) border and the top of the iliac crest perpendicular to the long axis of the trunk, with Lufkin W606PM flexible steel tape according to the ISAK (Marfell-Jones *et al.,* 2006). WC values which are age, sex, and ethnicity-specific that fall on the 75^{th} and 90^{th} percentile are important in the identification of children and adolescents at risk for various comorbidities such as CVDs, hyperinsulinaemia, and type two DM (Fernández *et al.,* 2004).

Blood pressure (BP) measurement

Measurements were taken on the left arm using the Omron MIT Elite Plus (Omron Healthcare Co., Ltd, Japan). Participants were asked to lie down and rest for five minutes before BP measurements were taken, talking was not permitted during the resting period, nor when the BP measurement was being taken. The average measurements from two separate measurements at least five minutes apart were used in the analysis. A measurement of SBP >130 millimetre of mercury (mmHg) and DBP >85 mmHg is classified as abnormal according to the International Diabetes Federation (IDF) cut point, and SBP $\geq 90^{th}$ percentile (Alberti *et al.,* 2006; Jolliffe & Janssen, 2007) for the whole population is considered abnormal according to the National Cholesterol Education Program/Adult Treatment Panel III (NCEP/ATP III) criteria.

Ethical considerations

All procedures followed were in accordance with the ethical standards of the North West University Ethics Committee and the Helsinki Declaration. Written informed consent was obtained from the school authorities, the parents and the pupils of the participating schools. Clearance by the Ethics Committee of North West University, Potchefstroom campus (Ethics number: NWU-0058-01-A1) was granted.

Data analyses

Descriptive (i.e. means, standard deviations and frequencies) characteristics were used to calculate the changes in body composition, PA and metabolic risk factors (i.e. abdominal obesity and BP). Analysis of variance (ANOVA) for repeated measures was calculated for changes in the body composition, PA and selected metabolic risk factors for 2011, 2012 and 2013 data. In addition, partial *E*ta-squared (η_p^2) of ANOVA for repeated measures was used to determine the effect sizes of changes in the body composition, PA and selected metabolic risk factors (i.e. abdominal obesity and BP), and 95% confidence interval (CI). Partial *E*ta-squared of ANOVA is in agreement with Cohen's rule of thumb whereby values of η_p^2 are interpreted as follows: = 0.01, 0.06 and 0.14 were regarded as small, medium and large effects, respectively. Data analyses for all the variables were calculated using the Statistical Package for Social Sciences (SPSS) version 20.0 programme and the level of significance was set at $p \leq 0.05$.

3.4 RESULTS

Figure 1 presents the overall percentage distribution of BMI categories for the total group of learners for the period 2011, 2012 and 2013. The BMI classification of both boys and girls shows that during the period 2011–2012, underweight decreased by 5.7% and increased by 5.1% during the period 2012–2013. A percentage of 70% of the group was in the normal weight category during the period 2011, with a 2.2% increase in 2012 (to 73.1%), and a 9.2% decrease (to 63.9%) in 2013. In 2011, 12.8% of the group was overweight, the prevalence of overweight increased by 3.5% in 2012, with a further increase of 4.1% in 2013, resulting in an overall increase of 7.6% during the entire period 2011–2013.

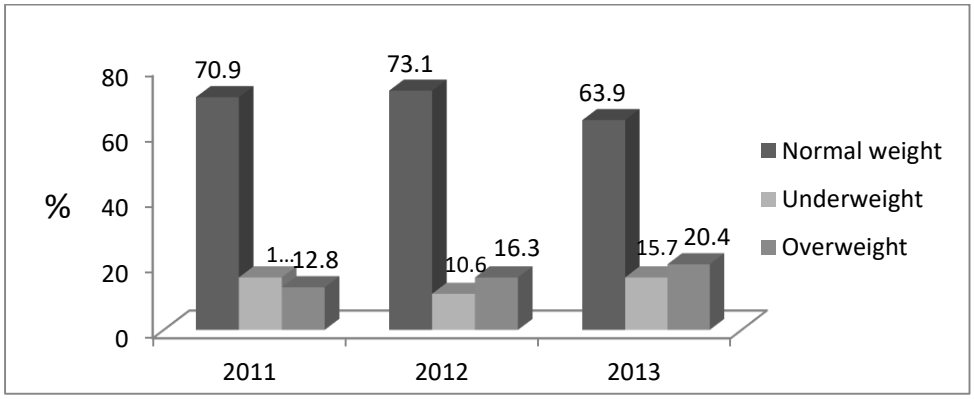

Figure 1 BMI distributions for three categories of normal weight, underweight and overweight for the total group for three measurement points

Table 1 shows the BMI and the International Obesity Taskforce (IOTF) WC categories of normal weight, underweight, overweight and obese for the total group for three measurement points. The IOTF WC distributions indicate that 6.3% of the adolescents were overweight in 2011 (WC >1.3SD) while 4.9% was obese (WC >2.3SD). In 2012, the number of overweight adolescent boys and girls decreased to 6.1% while that of obese adolescents increased to 6.1%. In 2013 the number of overweight adolescents increased by 6.5% to 12.6% while that of obese adolescents decreased by 2.4% to 3.7 percent.

Table 1 BMI and WC distributions for the total group for three measurement points

BMI classification	**2011 (boys and girls)**		**2012 (boys and girls)**		**2013 (boys and girls)**	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**
Underweight -BMI <17.5	47	16.3	24	10.6	30	15.7
Normal -BMI >17.6 to 24.9	205	70.9	166	73.1	122	63.9
Overweight -BMI >25	37	12.8	37	16.3	39	20.4
Waist circumference (cm)						
Normal WC (<1.3SD)-IOTF	257	88.9	199	87.7	160	83.8
Overweight WC(>1.3SD)	18	6.3	14	6.1	24	12.6
Obese WC (>2.3SD) IOTF	14	4.9	14	6.1	7	3.7
Total	289	100.0	227	100.0	191	100.0

Key: BMI = body mass index; WC = waist circumference; IOTF = international obesity taskforce

Figure 2 presents data on the percentage distribution of BMI categories of participants by gender for the period 2011, 2012 and 2013. More boys than girls were in the underweight category at each of the measurement points. The number of overweight adolescents showed a gradual rise for both adolescent boys and girls during the entire measurement period. Among the adolescent boys and girls, overweight increased by 2.2% and 12.2%, respectively. The overall increase in overweight during the entire measurement period was higher among the girls than the boys.

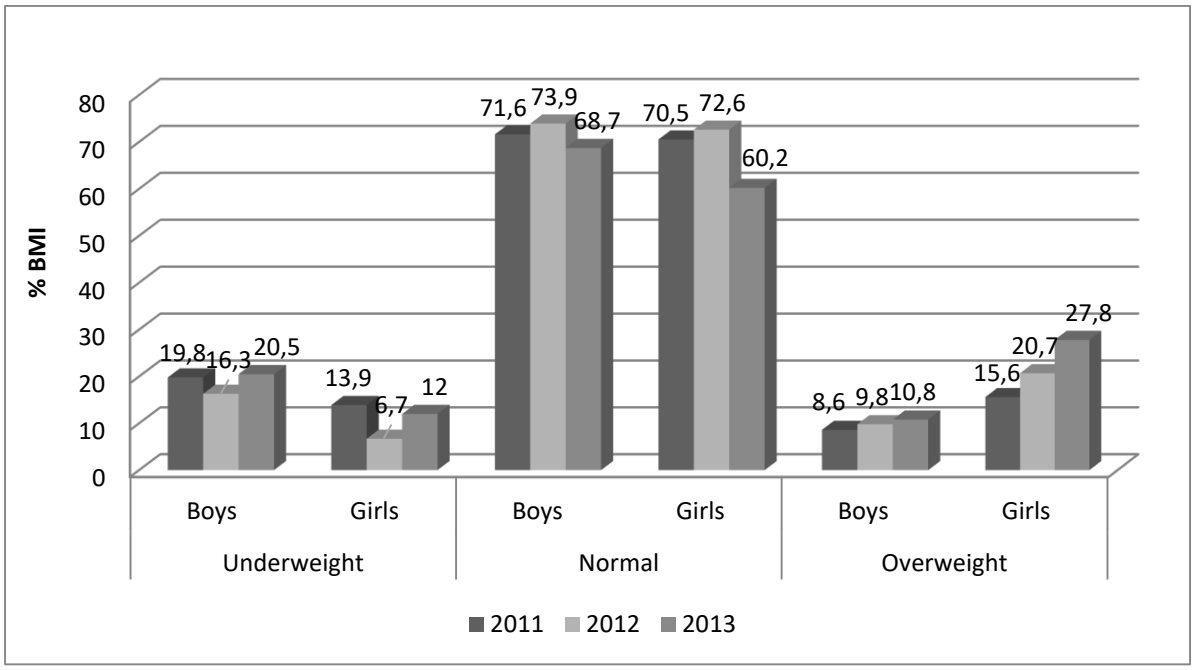

Figure 2 Percentage distribution of BMI categories by gender of participants for 2011, 2012 and 2013

Figure 3 shows the WC distributions for the three categories of normal weight, overweight and obese for the adolescent boys and girls for the three measurement points in 2011–2013. The distribution shows that in 2011 more girls (7%) than boys (5.2%) were in the overweight category (WC >1.3 SD) according to the IOTF classification. In 2012, the percentage of boys in the overweight category slightly decreased (0.9%) while that of girls increased (0.3%). In 2013, the percentage of boys and girls in the overweight category substantially increased (9% and 4.7%) respectively. The percentage of adolescent boys in the IOTF obese category (WC >2.3SD) increased by 1.6% (boys) and 1% (girls) in 2012 and decreased by 2.8% (boys) and 2.3% (girls) in 2013.

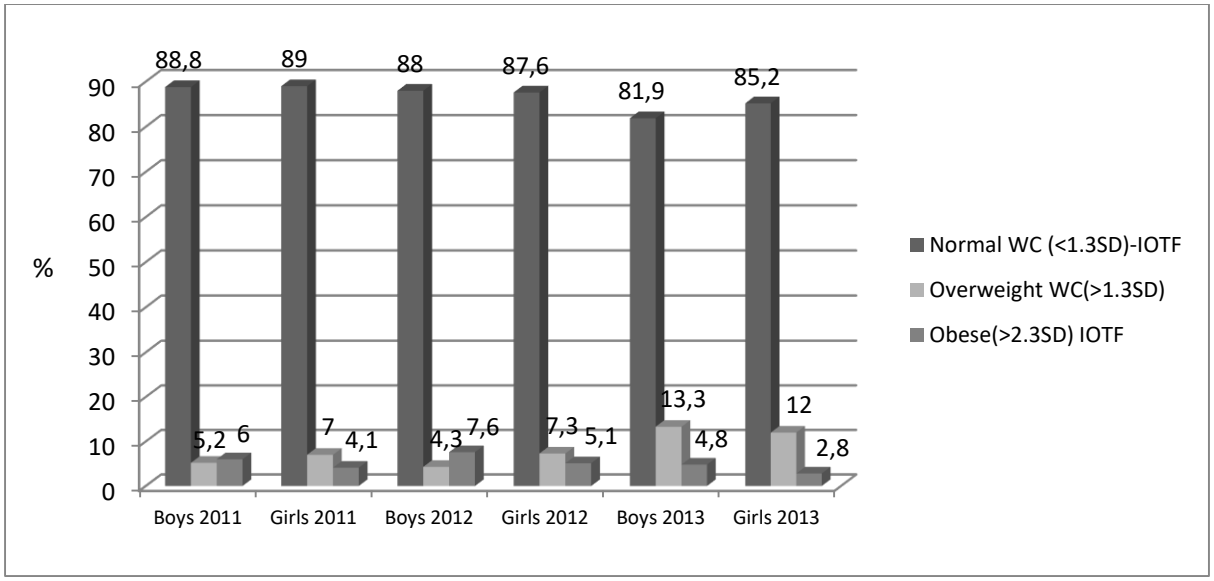

Figure 3 WC distributions for the three categories of normal weight, overweight and obese for the total group for three measurement points

Table 2 shows descriptive data for gender differences in body composition, selected metabolic risk factors and PA status of both boys and girls in 2011, 2012 and 2013. There was a significant change in height (p <0.001 and η_p^2= 0.53) for boys compared to girls during the measurement period. The height of boys increased by 5.74 cm compared to the girls (1.09 cm) during the period.

The body composition data revealed that during the measurement period the boys recorded a substantial overall increase in body mass of 6.95 kg while among the girls an increase of 3.93 kg in body mass was recorded. The increase was also greater in boys than in girls (p <0.001 and η_p^2= 0.57). There were inconsistent changes in skinfold thickness and %BF, with both variables showing a decrease in 2012 and an increase in 2013 for both boys and girls. The change in the sum of skinfolds was significantly higher in girls (p = 0.001 and η_p^2 = 0.39) than in boys, while %BF increase was significantly greater in boys (3.61%) than in girls (1.44%) (p < 0.001 and η_p^2 = 0.42).

The data on metabolic risk factors (abdominal obesity and BP) showed that among the boys WC increased (2.97 cm) between 2011 and 2013. For girls, the increase in WC was significantly lower (0.73) compared to boys during the same period. Both systolic (SBP) and diastolic (DBP) blood pressure increased (6.39 mmHg and 5.41 mmHg respectively) among the boys during the measurement period. For girls an overall increase of 5.59 mmHg in SBP and 2.25 mmHg DBP was noted. The difference of changes in metabolic risk factors between boys and girls was significant (p < 0.001 and η_p^2= 0.25 WC; 0.21 SBP; 0.20 DBP).

The PA data showed an increase of 608.28 METS among the boys and 214.3 METS among the girls. There were inconsistent changes in vigorous PA (VPA) and moderate PA (MPA) with both variables

decreasing in 2012 and increasing in 2013 for both boys and girls. The changes were higher in boys compared to girls (p = 0.001 and η_p^2= 0.07) for total PA; (p = 0.01 and η_p^2= 0.5) for VPA; and (p = 0.01 and η_p^2= 0.03) for MPA.

Table 3 presents the PA percentage scores for the total group of adolescent boys and girls. The percentage of adolescent boys and girls in the LPA category was inconsistent in that it increased from 34.2% (2011) to 48.4% (2012) and then decreased by 42.4% (2013). Overall participation in LPA increased (by 8.2%) during the two years of measurement while participation in MPA for the whole group gradually declined, resulting in a total decline of 15.2% during the entire measurement period. The number of adolescent boys and girls in the HPA category was inconsistent, increasing from 35.3% in 2011 to 34.8% in 2012, and 42.4% in 2013, resulting in an overall increase of 7.1% in HPA.

Table 2 Percentage score (%) for physical activity for the total group

Physical Activity	**2011 (boys and girls) n=289**		**2012 (boys and girls) n=116**		**2013 (boys and girls) n=173**	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**
Low PA (METS <200)	63	34.2	89	48.4	78	42.4
Moderate PA (METS>200 to <500)	56	30.4	31	16.8	28	15.2
High PA (METS >500)	65	35.3	64	34.8	78	42.4
Total	184	100.0	184	100.0	184	100.0

Figure 4 presents the comparisons of PA distributions for the three categories of low, moderate and high for the boys and girls for the period 2011–2013. More boys than girls were in the HPA category while more girls than boys were in the LPA category at each measurement point. Overall HPA increased by 3.2% among the boys and 0.9% for the girls. On the other hand, participation in LPA overall increased among the boys (17.2%) than among the girls (9.2%) during the entire measurement period.

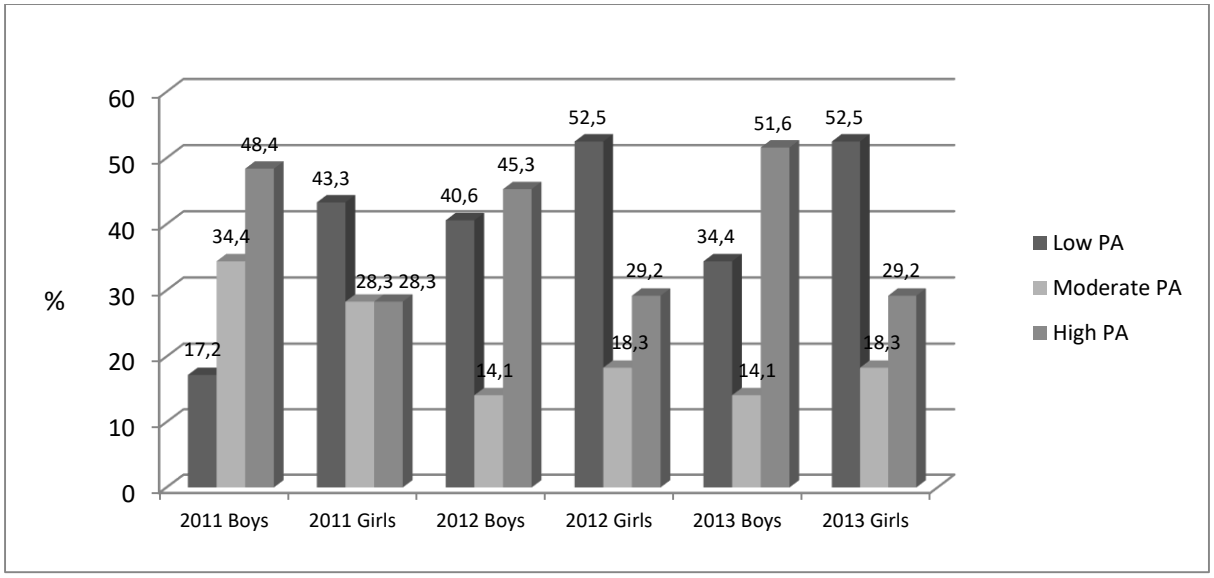

Figure 4 PA distributions for the three categories of low, moderate and high for the total group for three measurement points

Table 4 shows the percentage scores (%) of BP for the total group for the three measurement points. A percentage of 90.3% of the adolescent boys and girls were in the normal BP category. The number decreased by 8% in 2012 and then increased by 3% to 85.3% in 2013, giving a 5% total decrease for the entire measurement period. The percentage of 9.7% of the group was in the prehypertensive/hypertensive category (with SBP 90th <95th or > 95th percentiles). The number of adolescents in this category increased from 8% to 17.7% in 2012, and decreased by 3% to 14.7% in 2013 with a total increase of 5% for the entire measurement period.

Table 3 Percentage scores (%) blood pressure for the total group for three measurement points

BMI classification	**2011 (boys and girls) n=289**		**2012 (boys and girls) n=116**		**2013 (boys and girls) n=173**	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**
Normal (Systolic BP<90 Percentile)	205	90.3	181	82.3	163	85.3
Prehypertension/ Hypertension (Systolic BP 90th to <95th/>95th)	22	9.7	39	17.7	28	14.7
Total	227	100.0	220	100.0	191	100.0

Figure 5 presents data on the HBP risk between adolescents by gender of participants during the period 2011 and 2013. In 2011, more boys (15.3%) than girls (5.4%) were in the prehypertension/ hypertension category. The number of girls in the prehypertension/ hypertension category increased (by 14.3%) in 2012 and insignificantly decreased (0.3%) in 2013 while the number of boys in the prehypertension/hypertension category gradually decreased, resulting in an overall decrease of 6.9% during the entire two-year period.

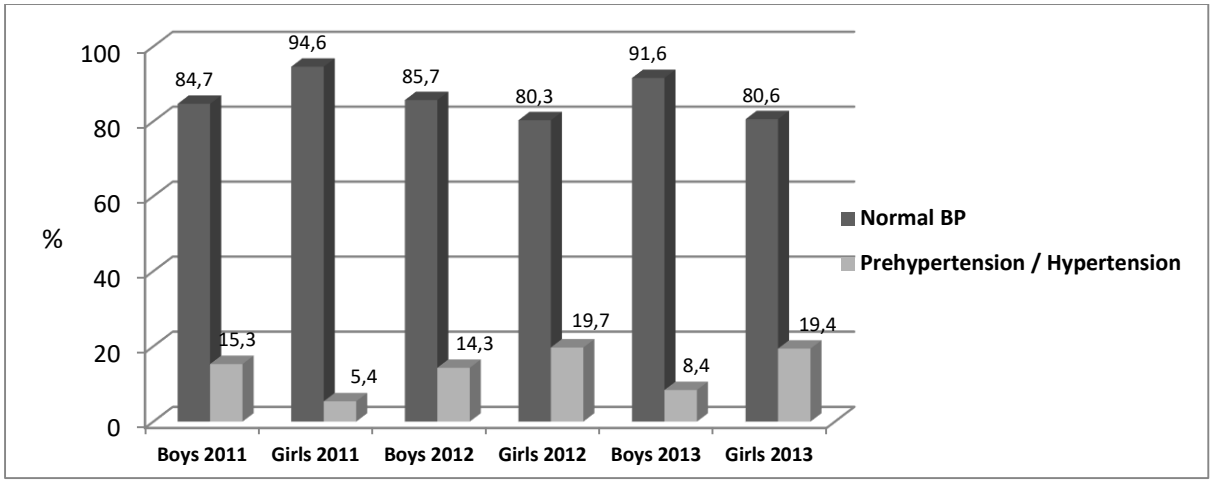

Figure 5 Percentage scores (%) for blood pressure distributions for three categories of normal and prehypertension or hypertension for the boys and girls for three measurement points

Table 4 Participants' body composition, metabolic risk factors and physical activity characteristics from 2011 to 2013 (mean, standard deviation (SD))

	2011		2012		2013			
	Males (n=116)	Females (n=173)	Males (n= 92)	Females (n=135)	Males (n=83)	Female (n=108)	η_p^2	P-values of within the subjects contrasts
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD		
Body composition								
Stature (cm)	165.29±9.39	157.88±6.94†	168.74±9.06	158.53±7.07†	171.03±8.05	158.97±7.27†	.53	<0.001
Body mass (kg)	55.24±13.5	53.7±12.8†	59.65±14.95	56.27±12.96††	62.19±13.85	57.63±12.75††	.57	<0.001
Sum of skinfolds (mm)	19.19±9.65	31.54±13.88†	13.91±7.88	23.42±10.1†	18.69±9.46	30.21±10.40†	.39	<0.001
%Body fat	13.4±8.21	24.1±10.35†	8.73±7.25	20.11±6.1†	17.01±7.14	25.24±6.37†	.42	<0.001
BMI (kg/m^2)	20.01±3.63	21.43±4.36†	20.75±3.97	22.31±4.43†	21.11±3.61	22.75±4.52††	.35	<0.001
Selected metabolic risk factors								
Waist circumference (cm)	68.07±8.13	67.61±8.67†	69.82±8.89	68.05±9.2††	71.04±8.54	68.34±8.32††	.25	<0.001
Systolic blood pressure	105.72±11.19	100.67±8.39†	110.72±12.29	105.24±10.63†	112.11±7.76	106.26±9.93†	.21	<0.001
Diastolic blood pressure	67.67±8.97	67.75±6.93	69.51±9.35	65.89±7.49†	73.08±7.70	70.00±8.49††	.20	<0.001
Physical activity								
Vigorous (METS)	213.91±357.47	134.87±295.55	687.51±1780.69	210.27±539.11	268.80±423.94	117.40±308.71†	.05	0.01
Moderate (METS)	71.20±159.43	57.82±161.49	459.82±1835.93	82.74±196.01	55.80±97.05	21.36±46.43†	.03	0.01
Total PA (METS)	648.79±525.12	423.68±513.57††	1052.15±2160.15	432.85±695.53†	1257.07±2192.75	637.98±939.95†	.07	0.001

†= (p<0.001; significant difference between boys and girls); ††= (p=0.01; significant difference between boys and girls); *%BF = percentage body fat; METS = metabolic equivalent units; PA = physical activity, η_p^2 = Partial Eta Square.*

3.5 DISCUSSION

This present study examines the longitudinal changes in body composition, PA and selected metabolic risk factors (abdominal obesity and BP) among 14- to 16-year old high school adolescents from the Tlokwe local municipality, Potchefstroom, South Africa.

The results of the study showed that adolescent girls were significantly more obese than the boys, with girls having consistently greater BMI, sum of skinfolds and %BF. There was a gradual increase in overweight among adolescent boys and girls during the measurement period. At every measurement point, the girls were considerably more overweight than the boys. A greater increase in overweight during the entire measurement period was noted among the girls (12.2%) than the boys (2.2%). In the long term, childhood obesity tends to persist into adulthood, increasing the risk for obesity-related morbidities such as CVDs, hypertension, type two DM and some forms of cancer (Bailey *et al.*, 2015; Salonen *et al.*, 2015). This shows that adolescent girls may be at a higher risk of being obese and developing obesity-associated illnesses. The prevalence of overweight in the current study was lower than the 25% for girls and 8% for boys (overweight and obesity) from Gauteng Province (Ginsburg *et al.*, 2013). However, the findings are in contrast with those of Thibault *et al.* (2010) who noted that French adolescent boys were more overweight (obesity included) than girls ($p < 0.01$) as well as those of Conolly (2016) who found that more boys (30%) than girls (26%) sampled in England were overweight and obese. A substantial increase in indices of overweight found among adolescents in this study reflects the extensively documented trend in increased childhood overweight and obesity. Many studies have reported that childhood overweight and obesity is on the rise globally (WHO, 2012; Ng *et al.*, 2014; Wabitsch *et al.*, 2014). The increase in indices of overweight found in this study also confirms the findings from earlier studies that childhood obesity is on the rise among South African children and adolescents (Draper *et al.*, 2014; Moselakgomo *et al.*, 2015; Pienaar, 2015).

The current study noted that overweight and obesity was more prevalent among adolescent girls compared to the boys. There was a decrease in sum of skinfold thickness and %BF in both boys and girls during the second point of measurement in 2012. This decrease could be due to a corresponding increase in moderate and vigorous PA which was noted during the same period.

Physical inactivity and sedentary behaviour have been noted as some of the main contributors to overweight and obesity that result in an increased risk of developing metabolic-related diseases. Despite the fact that the risks associated with PI and a sedentary lifestyle as well as health benefits of regular PA are well known, many children across the world prefer a sedentary lifestyle (Tremblay *et al.*, 2016). Several studies have found that decreasing the daily PA level can lead to a considerable increase in body mass (Toriola & Monyeki, 2012; Ng *et al.*, 2014; Salonen *et al.*, 2015). The current study shows that participation in LPA was on the increase, from 34.2% (2011) to 48.4% (2012) but then decreased

to 42.4% in 2013 while participation in MPA was on the decline. The gradual decline in MPA and the considerable LPA levels found among adolescent boys and girls in this study support the findings of earlier studies that PA is on the decline among SA children and adolescents (Toriola & Monyeki, 2012; Draper *et al.,* 2014). This also confirms the widely reported assertions that many children and adolescents do not meet the globally recommended daily MVPA (Tremblay *et al.,* 2016).

Participation in PA by gender in this study shows that boys participated in PA more than girls. At any measurement point, more girls were in the LPA category than boys. In the HPA category, there were more boys than girls at each measurement point. Thibault *et al.* (2010) reported that more French boys (80.8%) than girls (66.8%) engaged in PA during leisure time. Similar gender variations in PA participation has also been reported among boys and girls from the US (Caspersen *et al.,* 2000), Canada (Allison *et al.,* 2007) and European Union countries (Armstrong & Welsman, 2006).

Concerning the risk of developing metabolic-related diseases, adolescent boys and girls in this sample are currently at lower risk. In terms of metabolic risk factors, the adolescent boys in this sample have greater WC and SBP at every point of measurement, compared to the girls. DBP for boys was also substantially greater than that of girls for the years 2012 and 2013. Of major interest is the upward trend of these risk factors in both boys and girls, particularly WC and SBP. This could mean that if the situation remains unabated the adolescent boys and girls in this sample could be at greater risk of developing chronic diseases such as CVDs, hypertension, type two DM and other metabolic-related diseases later in life.

Limitations of the study

The study sample consisted of six high schools in the Tlokwe municipality in Potchefstroom in the North West Province of South Africa. Therefore, the findings of this study is not representative of all adolescents in the Tlokwe municipality, the North West Province or the whole of South Africa. The use of IPAQ-S, which is based on activity recall, may be a limitation to the study. However, the use of IPAQ-S provides information on the frequency and time spent walking and engaging in other MVPA as well as time spent sitting in the past seven days.

CONCLUSION

Overweight among the 14-yearold high school adolescents living within the Tlokwe local Municipality of Potchefstroom is gradually increasing, and the increase is higher among adolescent girls compared to the boys. The increase in metabolic risk factors (SBP and WC) is higher among the boys than the girls, while participation in moderate MVPA is declining more among the girls compared to the boys. Although the majority of the adolescents were in the normal BP category and currently at less risk of

developing metabolic diseases, the upward trend of overweight, %BF, WC and SBP and PI could put the adolescents at risk of metabolic illnesses in future if no intervention strategies are instituted.

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CHAPTER 4
THE RELATIONSHIP BETWEEN TWO-YEAR LONGITUDINAL CHANGES IN BODY COMPOSITION, PHYSICAL ACTIVITY AND TELEVISION WATCHING AMONG ADOLESCENTS FROM POTCHEFSTROOM IN THE NORTH WEST PROVINCE OF SOUTH AFRICA: THE PAHL STUDY

The manuscript will be submitted to the *South African Journal for Research in Sport, Physical Education and Recreation.* As such, the referencing style used in this chapter is in line with the journal's guidelines.

The relationship between two-year longitudinal changes in body composition, physical activity and television viewing among adolescents from Potchefstroom in the North West Province of South Africa: the PAHL study

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4.1 ABSTRACT

Low physical activity (LPA) and excessive television (TV) watching time are associated with the development of childhood obesity. The purpose of this study was to determine the relationship between two-year longitudinal changes in body composition, physical activity (PA) and TV watching time among adolescents from Potchefstroom in the North West Province of South Africa. A total of 289 adolescents (116 boys and 173 girls) aged 14.9±0.76 participated in the study. The anthropometric measures of height, body mass and skinfolds thickness (triceps and subscapular skinfolds), were measured using the standard procedures described by International Society for the Advancement of Kinanthropometry (ISAK). Subsequently, body composition measure of body mass index (BMI) was derived by height divided by weight squared, and sum of triceps and subscapular was used to calculated for percentage body fat (%BF) these anthropometric measurements were converted to body composition. PA level was measured using the short form International Physical Activity Questionnaire (IPAQ-S) and TV watching time was collected through self-reports. Overweight increased by 7.6% (from 12.8% in 2011 to 20.4% in 2013) for the group with more girls being overweight than boys ($p<0.01$). The decrease in moderate physical activity (MPA) was greater among girls (36.46 MET.min/week) than boys (15.4 MET.min/week). TV watching time increased significantly for both boys and girls ($p<0.001$). There was no significant relationship between changes in body composition, PA and TV watching time. However, changes in TV watching time and BMI were both non-significant and negatively related to changes in moderate and vigorous PA. After adjusting for age, the regression coefficient indicated a significantly negative relationship between changes in BMI and changes in total PA among boys ($p=0.02$). A similar relationship was also noted between changes in the sum of skinfolds and changes in MPA among girls ($p=0.04$). It was concluded that changes in PA and TV watching time have no combined effects on body composition and both (PA negatively and TV watching time positively) are independently related to body composition variables. Age is an important factor between body composition and PA.

Keywords: Television watching time; Childhood obesity; Physical activity, Sedentary behaviour, Adolescents

4.2 INTRODUCTION

The transition from childhood to adolescence appears to be a critical phase in children's growth and development, during which sedentary behaviour increases (Pearson *et al.,* 2017). A sedentary lifestyle is commonly associated with clustered metabolic risk factors, mental health issues, increased morbidity and mortality in adults, (Marshall & Ramirez, 2011; Wennberg *et al.*, 2014). An emerging body of evidence has shown that sedentary lifestyle is also associated with several risk factors of chronic diseases in children and adolescents (Tremblay *et al.*, 2011; Salonen *et al.*, 2015). Childhood refers to a person age 19 or younger, and defines an adolescent as any person between ages 10 and 19 (World Health Organization (WHO), 2018). As such and by definition of adolescent, the focuse of this study was on adolescent between the ages 14- and 16-year-old. It has been stated that adolescent is a critical time in life when people becomes independent individuals' forge new relationships, develop new social skills, and learn behaviours that will last for the rest of their lives. And, adolescent can be the most challenging period (WHO, 2018). These metabolic risk factors may track into adulthood, mostly in individuals who are overweight or obese in childhood and/or adolescence (Proctor *et al.,* 2003; Evensen *et al.*, 2016). Children who are physically active report healthier body mass and body composition (PA Guidelines Advisory Committee, 2008), and present a lower risk of developing obesity-related illnesses later in life compared to those who are physically inactive (Cassidy *et al.*, 2016).

Television (TV) watching is one of the most prevalent forms of sedentary behaviour that consumes the greatest proportion of leisure time across all age groups compared to other sedentary activities (Melkevik *et al.,* 2015; Pearson *et al.,* 2017) and is now understood to be an independent health risk (Tremblay *et al.,* 2011; Shibata *et al.*, 2016). The mechanism by which TV watching time contributes to the development of weight gain is unclear (Dennison & Edmunds 2008). However, it has been widely hypothesised that long episodes of TV watching reduces energy expenditure, primarily by decreasing the time spent on PA (Tremblay *et al.,* 2011; Smith *et al.*, 2015), and therefore lowers the resting metabolic rate (Borghese & Chaput, 2013) and increases energy intake due to excessive snacking (Robinson, 2001; Rosiek *et al.,* 2015).

One of the common approaches for preventing excess weight gain includes increasing energy expenditure by engaging in moderate-vigorous physical activity (MVPA). MVPA can attenuate the increase in body mass, body mass index (BMI) and waist circumference (WC), and reduce the risk of obesity (Shibata *et al.,* 2016). Spending less time on MVPA together with long hours of TV watching and other screen-related activities is associated with increased risk of obesity and the prevalence of other causes of mortality and morbidity such as cardiovascular disease (CVD) (Tremblay *et al.,* 2011). On the other hand, maximising participation in MVPA improves fat oxidation and other determinants of obesity (Katzmarzyk *et al.,* 2015; Melkevik *et al.,* 2015).

Evidence from cross-sectional studies showed an independent and combined association of PA, TV watching time and adiposity among children and adolescents (Heelan & Eisenmann, 2006; Rivera *et al.,* 2010; Melkevik *et al.,* 2015; Shibata *et al.,* 2016). Similar findings were confirmed in longitudinal studies (Andersen *et al.,* 1998; Proctor *et al.,* 2003; Mitchell *et al.,* 2013). For example, the Framingham Children's Study (Proctor *et al.,* 2003) showed that 11-year old children with low PA levels and high TV watching time had the greatest gains in BF and sum of skinfolds compared to those who had high PA levels over a seven-year follow-up period. Similarly, children who watched more TV were reported to be less likely to engage in PA and had high BMI over a period of five years (Mitchell *et al.,* 2013). The association of adiposity with PA (negatively associated) and TV watching time (positively associated) was found to be stronger among obese than non-obese children and adolescents from Jordan (Al-Dalaeen & Al-Domi, 2017). However, some studies reported a low and statistically insignificant relationship (Robinson *et al.,* 1993; Hanley *et al.,* 2000; Robinson *et al.,* 2001), hence the available evidence concerning the relationship between adiposity, PA and TV watching time seems to be inconclusive.

Longitudinal data on the association between changes in body composition, PA and TV watching time among adolescents who live in the Tlokwe municipality in the Potchefstroom area of South Africa is lacking. It is thought therefore that this study will not only address the above specific paucity but may contribute significantly to the existing global literature in this field. The lack of studies that explore the longitudinal association between changes in body composition and PA in relation to changes in TV watching time among adolescents in South Africa hampers the development of national recommendations for TV watching norms for South African children and adolescents as a measure of preventing the development of weight-related illnesses among this population. Thus, the purpose of this study is to determine the relationship between two-year longitudinal changes in body composition, PA and TV watching time among adolescents from the Tlokwe municipality in the North West Province of South Africa. It is hypothesized that there will be a significant positive relationship between two-year longitudinal changes in body composition, PA and TV watching time among adolescents from Potchefstroom in the North West Province.

4.3 METHODOLOGY

Research design

The present study was part of a larger study – Physical Activity and Health Longitudinal Study (PAHLS) (Monyeki *et al.,* 2012). This study started in 2010 and ended in 2014 following a mixed longitudinal design to evaluate the development of determinants of health risk factors and PA among 14–18-year old high school learners in the Tlokwe municipality of Potchefstroom in the North West Province of South Africa (Monyeki *et al.,* 2012). Data from three measurement points 2011, 2012 and

2013 were used to determine the longitudinal relationship between changes in body composition, PA and TV watching time among 14- to 16-year old adolescent learners.

Permission to conduct the study was granted by the District Manager of the Department of Basic Education in Potchefstroom, North West Province prior to the commencement of data collection. The Ethics Committee of North-West University approved the study (Ethics number: NWU-0058-01-A1).

Participants

Two hundred and eighty-nine (289) high school learners (116 boys and 173 girls) aged 14.9±0.76 years were randomly selected from the six high schools and gave consent to participate in the study. Two schools were from the central business district (CBD), mostly comprising children from high socioeconomic households while the other four schools were from the township areas with adolescents mostly from low socio-economic households. A dropout rate of 21% (2012) and 33% (2013) from the 2011 measurement point was observed. The observed dropout rate was due to participant absenteeism during the day of measurements, a dropout from the school or transfer from one school to another. These reasons for dropout were beyond the study's control, hence subject attrition did not have a significant effect in the analyses of the objectives of the current study. Detailed information concerning the participants and methods of data collection have been published elsewhere (Monyeki *et al.*, 2012).

Body composition measurements

The participants' height, body mass and skinfolds thickness (triceps and subscapular skinfolds), were measured using the standard procedures described by International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones *et al.*, 2006). All anthropometric sites were measured twice by Level 2 ISAK certified anthropometrists. BMI was calculated as body mass/stature² (kg/m²). Age-specific BMI values for children were applied to determine the categories of the participants as overweight, normal weight and underweight respectively (Cole *et al.*, 2007). Percentage BF was computed from the subscapular and triceps skinfolds values based on the Slaughter *et al.* (1988) equation.

Measurement of physical activity (PA)

PA was assessed using the short form of the International Physical Activity Questionnaire (IPAQ-S) (WHO, 2002). The IPAQ-S was administered to the participants under the supervision of the principal investigator before the anthropometric measurements were conducted. The short form questionnaire consists of seven items that identify the (self-reported) frequency and time spent on walking and engaging in other MVPA during the last seven days prior to the administration of the questionnaire. In the IPAQ-S only those sessions lasting ten minutes or more were analysed. All aspects of PA related to

occupation, transportation, household chores, and leisure time activity were included in analyses. IPAQ-S also elicits information about the time spent sitting which is used as an indicator of inactivity. The PA of participants was classified into three categories, namely: Low activity metabolic equivalence tasks (MET) (<3 MET.min/week), moderate activity (3–6 MET.min/week), and high activity (>6 MET.min/week) according to the guidelines for data processing and analysis of the IPAQ. Total PA was calculated as the sum of all PA components performed in the previous seven days.

Television (TV) watching time

Participants self-reported the time spent watching TV per day within the past seven days of the week, and the time spent watching TV was classified as follow: don't know=0; less than one hour=1; two to three hours=2; and more than three hours=3. The participants were stratified according to their daily TV watching time in accordance with the Third National Health and Nutrition Examination Survey guidelines (Andersen *et al.,* 1998; Bryant *et al.,* 2007).

Data analyses

Descriptive (i.e. means, standard deviations (SDs), and frequencies) statistics were used to calculate the changes in body composition, PA and TV watching time. A non-parametric test was used to compute data not normally distributed. Analysis of variance (ANOVA) for repeated measures was calculated for changes in the body composition, PA and TV watching time for 2011, 2012 and 2013 data. In addition, partial *E*ta-squared (η_p^2) of ANOVA for repeated measures was used to determine the effect sizes of changes in the body composition, PA and TV watching time. Partial *E*ta-squared of ANOVA are in agreement with Cohen's rule of thumb whereby values of η_p^2 are interpreted as follows: = 0.2, 0.5 and 0.8 were regarded as small, medium and large effects, respectively. To determine the two-year longitudinal relationship between body composition changes, PA and TV watching time, a partial correlation coefficient adjusted for age and baseline measurements was performed. To further determine the relationships between the independent and dependent variables, a linear regression analysis adjusted for age was computed. Data analyses for all the variables were performed using the Statistical Package for Social Sciences (SPSS) version 25.0 programme (SPSS Inc., 2011) and the level of significance was set at $p \leq 0.05$.

4.4 RESULTS

The percentage distribution of BMI categories for the total group from 2011 to 2013 is shown in Table 1. The distribution shows that during the period 2011–2013, there were inconsistent changes in the underweight and normal weight categories. The percentage of underweight adolescents decreased (by 5.7%) in 2012 and increased (by 5.1%) in 2013 while in the normal weight category the percentage increased in 2012 (2.2%) and decreased in 2013 (by 9.2%). The percentage of overweight children

gradually increased (3.5% in 2012, and 4.1% in 2013), giving an overall increase of 7.6% during the entire measurement period.

Table 1 The BMI frequency of participants classified as underweight, normal and overweight for the total group

	2011		2012		2013	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**
Underweight	47	16.3	24	10.6	30	15.7
Normal BMI	205	70.9	166	73.1	122	63.9
Overweight BMI	37	12.8	37	16.3	39	20.4
Total	289	100	227	100	191	100

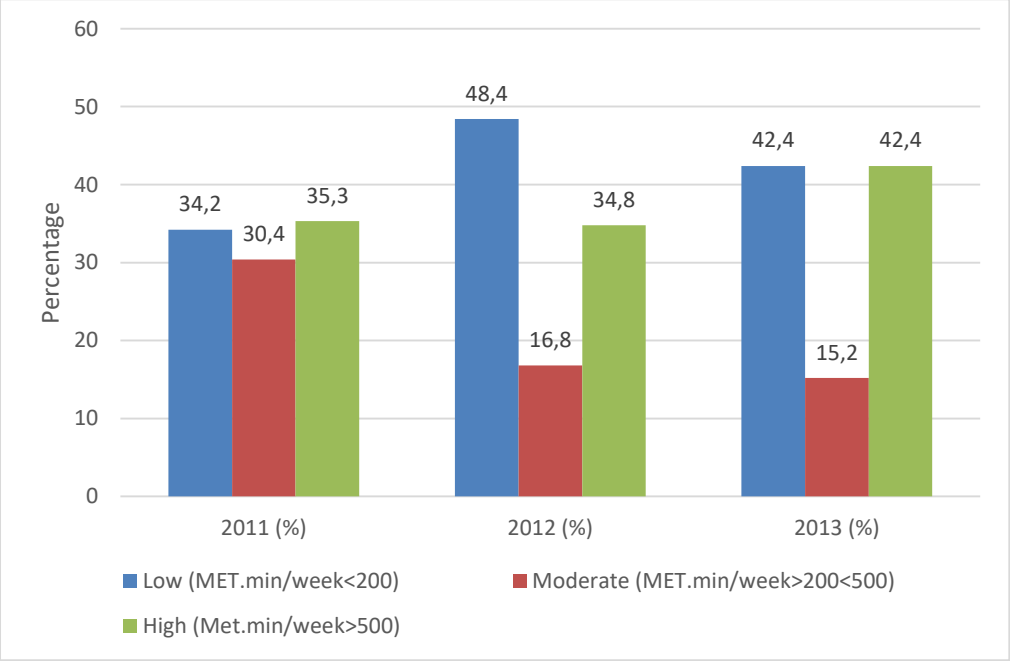

Figure 1 Percentage (%) score of PA classification for the total group for 2011, 2012 and 2013 measurement points

The data on PA classification (Figure 1) for the whole group reveals that 34.2% of the adolescents were in the low PA category in 2011. The number increased (14.2%) in 2012 and slightly decreased by 6% in 2013 resulting in an overall increase of 8.2% for the number of adolescents in the low PA category for the two-year period. MPA decreased by 15.2% during the measurement period, while the number of adolescents in the high PA category slightly decreased by 0.5% in 2012 and further increased by 7.6% in 2013 resulting in a 7.1% overall increase in the number of adolescents in the high PA category.

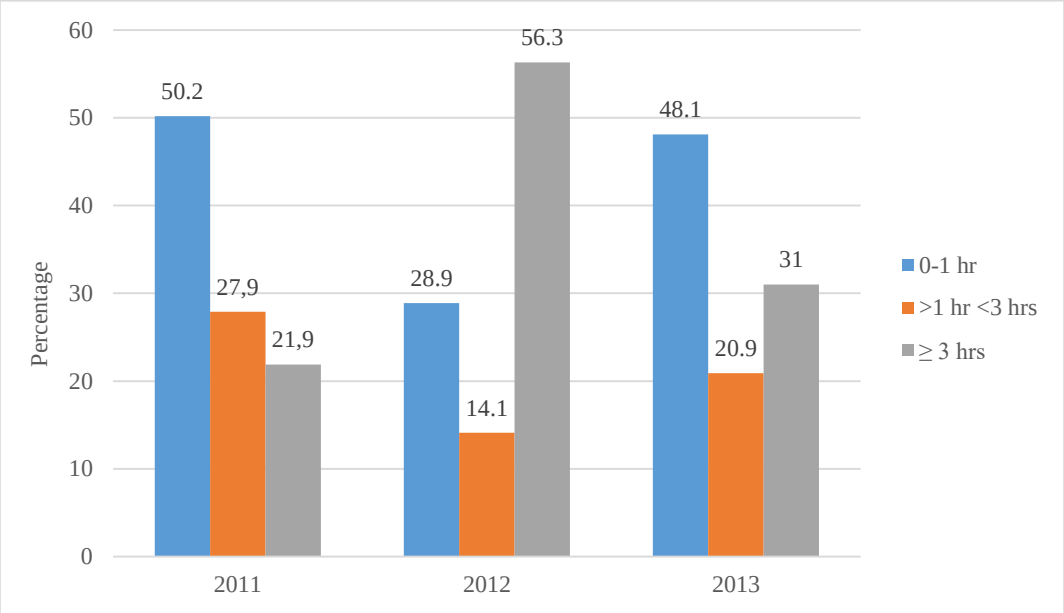

Figure 2 Percentage distribution of TV watching time for the total group

The data indicated that 50.2% of the adolescents watched TV daily for one hour or less in 2011 (Figure 2), 27.9% watched for between one and three hours while 21.9% watched for three hours and/or more. Between 2011 and 2012 the number of adolescents who watched TV for one hour or less decreased by 21.3%, the number of adolescents who watched between one and three hours also decreased (by 13.8%), while those who watched for three hours and more increased by 34.4%. Between 2012 and 2013 there was an increase of 19.2% in the number of adolescents who watched TV for one hour and less, the number of those who watched TV for between one and three hours decreased by 6.8%, while those who watched for more than three hours decreased by 16.9%. The overall percentage increases in the number of adolescents who watched TV for three hours and above increased by 9.1% during the entire measurement period.

Table 2 Percentage (%) score of boys' and girls' TV watching time

TV time	**2011**		**2012**		**2013**	
	Boys (n=116)	**Girls (n=173)**	**Boys (n=92)**	**Girls (n=135)**	**Boys (n=83)**	**Girls (n=108)**
0-1 hour	47.2	52.1	33.3	26.4	48.3	48
>1–3 hours	32.6	25	16.7	12.6	17.2	23
>3 hours	20.2	22.9	50	59.8	34.5	29

The data revealed that more girls than boys watched TV for three hours or more in 2011 and 2012 (Table 2). In 2013, the number of boys and girls who watched TV for three hours or more decreased to 34.5% and 29% respectively.

Table 3 Gender difference of participants' body composition, PA and TV watching characteristics

	2011		2012		2013			
	Males (n=116)	**Females (n=173)**	**Males (n= 92)**	**Females (n=135)**	**Males (n=83)**	**Female (n=108)**	**η_p^2**	**P-values of within the participants contrasts**
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD		
Body composition								
Stature (cm)	164.57±9.08	157.48±6.95†	168.34±8.33	158.04±7.03†	171.03±8.12	158.92±7.14†	0.53	<0.001
Body weight (kg)	54.30±11.96	53.44±12.99†	58.98±13.19	55.93±12.36††	62.28±13.81	57.88±12.83††	0.57	<0.001
Sum of skinfolds (mm)	19.02±9.05	31.05±13.59†	13.88±7.02	23.23±10.13†	18.67±9.50	30.08±10.31†	0.65	<0.001
%Body fat	13.24±7.75	23.47±10.21†	8.66±6.59	19.95±6.23†	16.97±7.14	25.34±6.34†	0.79	<0.001
BMI (kg/m^2)	19.87±3.08	21.45±4.51†	20.64±3.36	22.32±4.36†	21.15±3.59	22.86±4.54††	0.35	<0.001
Physical activity								
Moderate (MET.min/week)	71.20±159.43	57.82±161.49	459.82±1835.92	82.74±196.01	55.80±97.04	21.36±46.42†	0.06	0.04
Vigorous (MET.min/week)	213.91±357.5	134.87±295.5	687.51±1780.68	210.27±539.10	268.80±423.93	117.40±308.71†	0.05	0.01
Total PA (MET.min/week)	648.79±525.12	423.67±513.57††	1052.14±2160.15	432.85±695.53†	1257.07±2192.75	637.98±939.95†	0.07	0.002
Television watching								
Time (hours)	0.85±0.82	0.77±0.82	2.63±2.01	3.72±2.77††	3.41±4.62	2.98±3.49††	0.46	<0.001

†= (p<0.001; significant difference between boys and girls); ††= (p=0.01; significant difference between boys and girls)
% body fat = percentage body fat; PA = physical activity; η_p^2 = Partial Eta Square; SD = standard deviation

ANOVA for three repeated measures was performed to determine the significant differences between changes in body composition, PA and TV watching time among boys and girls for the periods 2011, 2012 and 2013. The data (Table 3) shows a mean change in height of 6.46 cm among the boys compared to the 1.44 cm for girls ($p<0.001$; $\eta_p^2 = 0.53$). Body mass increased by 7.98 kg among the boys and 4.44 kg among the girls. Boys were significantly heavier than girls ($p<0.001$; $\eta_p^2 = 0.57$).

With regard to indicators of adiposity, significant changes were found in sum of skinfolds thickness ($p<0.001$; $\eta_p^2 = 0.65$) and %BF ($p<0.001$; $\eta_p^2 = 0.79$), while BMI gradually increased in both boys and girls ($p<0.001$; $\eta_p^2 = 0.35$). In boys the total BMI increase was 1.28 kg/m^{2,} from 19.87 kg/m^2 to 21.15 (kg/m^2), and 1.41 kg/m^2 in girls, from 21.45 kg/m^2 to 22.86 kg/m^2. The magnitude of the changes (ηp^2) for all the measures of anthropometry and body composition ranged from moderate to high, small effect in physical activity and moderate in TV watching.

Total PA increased among the boys by 608.28 MET.min/week from 648.79±525.12 MET.min/week in 2011 to 1257.07±2192.75 MET.min/week in 2013, and by 214.3 MET.min/week among the girls, from 423.67±513.57 MET.min/week to 637.98±939.95 MET.min/week ($p = 0.002$; $\eta p^2 = 0.07$). Changes in the VPA and MPA were varied, with both VPA and MPA decreasing from 2011 to 2012 and increasing from 2012 to 2013 for both boys and girls. The overall change in VPA for boys was 54.89 MET.min/week, from 213.91±357.5 MET.min/week in 2011 to 268.80±423.93 MET.min/week in 2013. For the girls, VPA overall decreased by 17.47 MET.min/week, from 134.87±295.5 MET.min/week to 117.40±308.71 MET.min/week. The changes were higher in boys compared to girls ($p = 0.01$; $\eta p^2 = 0.05$). MPA significantly declined in both boys and girls during the period 2011–2013. In boys, the total decline was 15.4 MET.min/week, from 71.20±159.43 MET.min/week to 55.80±97.04 MET.min/week, and by 36.46 MET.min/week for the girls, from 57.82±161.49 MET.min/week to 21.36±46.42 MET.min/week. The decline was significantly higher in girls than in boys ($p = 0.04$; $\eta p^2 = 0.06$). The overall change in TV watching time was 2.56 hours in boys, from 0.85 hours to 3.41 hours, and 2.21 hours in girls, from 0.77 hours to 2.98 hours. Greater changes were among the boys compared to the girls ($p < 0.001$; $\eta p^2 = 0.46$).

Table 4 Age and baseline measurements adjusted correlation coefficients between changes in body composition, the PA level for the total group

Variables		$^{\Delta}$TV watching time	$^{\Delta}$Vigorous PA	$^{\Delta}$Moderate PA	$^{\Delta}$BMI	$^{\Delta}$%BF	$^{\Delta}$SSF
TV watching time	r	-	-.12	-.13	.01	-.06	-.05
	p	-	.23	.19	.85	.56	.60
Vigorous PA	r	-.12	-	.23	-.07	.16	.09
	p	.23	-	.02	.49	.12	.39
Moderate PA	r	-.13	.23	-	-.06	.03	.03
	p	.19	.02	-	.55	.71	.75

†, correlation is significant at the 0.05 level (2-tailed).
BMI = body mass index; SSF = sum of skinfolds; %BF = percentage body fat

When the relationship between changes in body composition, PA and TV watching time for the total group was analysed, the results showed no significant (p>0.05) correlation between changes in body composition and/or PA and TV watching time (Table 4). Changes in TV watching time were negatively related to changes in VPA and MPA but the relationship was statistically non-significant. Changes in BMI were also negatively but non-significantly related to changes in both VPA and MPA.

Table 5 Age and baseline measurements adjusted correlation coefficients between changes in body composition and PA level for boys

Variables		$^{\Delta}$TV watching time	$^{\Delta}$Vigorous PA	$^{\Delta}$Moderate PA	$^{\Delta}$BMI	$^{\Delta}$%BF	$^{\Delta}$SSF
TV watching time	r	1.00	-.21	-.18	-.06	.03	.06
	p	.	.22	.30	.70	.83	.72
Vigorous PA	r	-.21	1.00	.20	-.06	.20	.25
	p	.22	.	.24	.72	.25	.14
Moderate PA	r	-.18	.20	1.00	-.00	-.03	.01
	p	.30	.24	.	.97	.84	.97

†, correlation is significant at the 0.05 level (2-tailed).
BMI = body mass index; SSF = sum of skinfolds; % BF = percentage body fat

Among the boys, a negative and non-significant relationship was found between changes in TV watching time and changes in both VPA and MPA, while a positive relationship was found between changes in TV watching time and changes in body composition variables (%BF and SKF) the relationship of which was non-significant (Table 5).

Table 6 Correlation coefficients for changes in body composition, PA variables and TV watching time for girls controlled for age, baseline measurements

Variables		$^{\Delta}$TV watching time	$^{\Delta}$Vigorous PA	$^{\Delta}$Moderate PA	$^{\Delta}$BMI	$^{\Delta}$%BF	$^{\Delta}$SSF
TV watching time	r	-	.01	-.04	.09	-0.09	-.07
	p	-	.90	.77	.47	0.51	.59
Vigorous PA	r	.01	-	.12	.01	0.08	-.01
	p	.90	-	.38	.89	0.56	.94
Moderate PA	r	-.04	.12	-	-.11	-0.10	-.11
	p	.77	.38	-	.40	0.48	.42

†, correlation is significant at the 0.05 level (2-tailed).
BMI = body mass index; SSF = sum of skinfolds; % BF = percentage body fat

Among the girls, a negative and non-significant (p>0.05) correlation was found between changes in TV watching time and changes in MPA as well as between changes in body composition variables (BMI, percentage BF, and the sum of skinfolds) and changes in MPA. A positive relationship was also found between changes in TV watching time and changes in BMI although it was not statistically significant (Table 6).

Table 7 Standardised regression coefficients (β) and p-values for the relationship between changes in body composition, PA and TV watching time

	Boys						**Girls**					
	'Crude'			**Adjusted for age**			**'Crude'**			**Adjusted for age**		
	B	*95% CI*	*p-value*	*B*	*95% CI*	*p-value*	*B*	*p-value*	*95% CI*	*B*	*95% CI*	*p-value*
BMI												
Vigorous PA	-0.01	-0.000;0.000	0.97	-0.01	-0.000;0.000	0.96	0.03	0.74	0.000;0.000	0.02	-0.000;0.000	0.83
Moderate PA	0.04	0.000;-0.000	0.75	0.04	0.000;-0.000	0.79	-0.17	0.11	-0.002; 0.000	-0.16	-0.002;0.000	0.14
Total PA	-0.31	0.000;0.000	0.02	-0.31	0.000;0.000	0.02	-0.02	0.81	-0.000;0.000	-0.00	0.000;-0.000	0.97
TV watching time	-0.05	-0.004;0.003	0.76	-0.05	-0.004;0.003	0.77	0.10	0.44	-0.002;0.004	0.11	-0.002;0.004	0.41
%BF												
Vigorous PA	0.22	0.000;0.001	0.09	0.23	0.000;0.001	0.11	0.02	0.87	-0.001;0.002	-0.01	-0.001;0.001	0.94
Moderate PA	0.07	0.000;0.001	0.61	0.05	0.000;0.001	0.72	-0.17	0.10	-0.007;0.001	-0.15	-0.007;0.001	0.14
Total PA	-0.20	-0.001;0.000	0.13	-0.01	0.000;0.000	0.95	-0.11	0.28	-0.001;0.000	-0.06	-0.001;0.001	0.60
TV time	0.04	-011;0.01	0.84	0.05	-0.011;0.014	0.78	-0.09	0.49	-0.015;0.007	-0.08	-0.014;0.008	0.55
Sum of skinfolds												
Vigorous PA	0.22	0.000;0.001	0.09	0.22	0.000;0.001	0.10	-0.06	0.59	-0.003;0.002	-0.08	-0.003;0.001	0.40
Moderate PA	0.07	0.000;0.001	0.26	0.07	0.000;0.001	0.63	-0.23	0.02	-0.014;0.-0.001	-0.21	-0.013;-0.000	0.04
Total PA	-0.21	-0.001;0.000	0.14	0.02	0.000;0.000	0.89	-0.01	0.93	-0.001;0.001	-0.10	-0.002;0.001	0.32
TV watching time	0.05	-0.011;0.014	0.79	0.05	-0.011;0.014	0.77	-.024	0.85	-0.019;0.016	-0.01	-0.019;0.016	0.93

BMI = body mass index; %BF = percentage body fat; TV = television; PA = physical activity; CI = confidence interval

To further examine the relationships between independent and dependent variables, three multiple linear regression models were computed (according to gender) using changes in BMI, %BF and the SSF as dependant variables respectively, and changes in PA and TV watching time as predictors at a 95% confidence interval (CI) (Table 7). A significant negative relationship was found between changes in BMI and changes in TPA before and after adjusting for age. A non-significant ($p>0.05$) negative correlation coefficient was also found between changes in BMI and changes in VPA, percentage BF and TPA as well as between changes in the sum of skinfolds and TPA. Among the girls, a significant negative correlation was found between changes in the sum of skinfolds and MPA before and after adjusting for age.

4.5 DISCUSSION

The longitudinal relationship between changes in body composition PA and TV watching time among adolescents in South Africa has not been explored. The current study aimed to determine the two-year longitudinal relationship between changes in body composition, PA and TV watching time among adolescents from Potchefstroom in the North West Province of South Africa. The main findings of this study showed that the relationship between changes in body composition, PA and TV watching time among adolescents in the current sample was statistically insignificant ($p>0.05$). The magnitude of the changes (ηp^2) for all the measures of anthropometry and body composition ranged from moderate to high, small effect in physical activity and moderate in TV watching. This is despite the fact that some studies on the relationship between body composition, PA and TV watching time have received widespread acceptance (DuRant *et al.,* 1994; Proctor *et al.,* 2003; Mitchell *et al.,* 2013). After adjusting for age, the regression coefficient indicated that there was a significant ($p<0.05$) negative relationship between changes in BMI and TPA among the boys over the three measurement periods. A similar relationship was also noted between changes in the SSF and MPA among the girls, implying that age is an influential factor in the relationship of body composition and PA.

Changes in TV watching time were negative and statistically non-significantly related to changes in MPA and VPA. Although changes in TV watching time were positively related to changes in %BF and SSF among the boys, the relationship was not statistically significant. In girls, both changes in TV watching time and BMI were non-significantly related to changes in MPA. However, the relationship was in the negative direction.

The findings of this study are consistent with the findings of Robinson *et al.* (1993); DuRant *et al.* (1994); Hanley *et al.* (2000) and Robinson *et al.* (2001) who found non-significant relationships between these variables. Earlier studies, such as Robinson *et al.* (1993), followed a group of female adolescents Northern California, for two years and found a weak association between changes in TVwatching time and obesity or PA, and the findings remain unchanged after adjusting for age and

race. Similarly, DuRant *et al.* (1994) found no simultaneous relationship between changes in adiposity, PA and TV watching time among American children but they reported that the relationship between changes in TV watching time and PA was weak and in the negative direction. The significant negative relationship between changes in BMI and TPA and between changes in the sum of skinfolds and MPA agree with the findings of Proctor *et al*. (2003), and Heelan and Eisenmann, (2006), who reported that PA was independently related to obesity.

On the other hand, the results of this study differ from those of (Andersen *et al.*, 1998; Smith *et al.*, 2015; Talat & El Shahat, 2016) who reported a significant association between changes in body composition (weight, BMI, %BF, SSF, WC) and TV watching time among children and adolescents. For example, Andersen *et al.* (1998) reported that VPA was low among children who watched TV for more than four hours a day and that TV watching time was positively associated with %BF and BMI. Similarly, Katzmarzyk *et al.* (2015) reported a significant association between low PA, high TV watching time and obesity. An American prospective study found that increases in sedentary behaviour from baseline to follow-up were associated with increases in BMI independent of PA (Mitchell *et al.*, 2013), implying that PA can be an important mediator of this relationship. The relatively non-significant association between changes in body composition, PA and TV watching time found in the current study may suggest that there are other factors that may have influenced the changes in body composition among young children and adolescents, such as diet and nutritional behaviour (Bowen *et al*., 2015). These factors were, however, beyond the scope of this study.

In the current study, VPA increased among the adolescent boys while it was found to decline among the girls. This is conceivable, as other studies have also reported that boys engage in more VPA compared to girls (Rivera *et al*., 2010; Tremblay *et al*., 2011). Rivera *et al*. (2010) found that Brazilian adolescent girls were less physically active compared to the boys.

Another important and concerning the finding of this study was that overweight gradually increased during the two-year study period. The adolescent girls had significantly greater values of BMI, the sum of skinfolds and %BF than boys. A similar trend was reported by Telford *et al*. (2016) who found that Australian adolescent girls had a higher %BF (28%) compared to the boys (23%). The changes in BMI over time in our study were significantly greater among the girls than the boys. This could be attributed to the greater overall decrease in both MPA and VPA as well as the corresponding decrease in VPA participation which was noted among the girls compared to the boys during the entire two-year measurement period. The prevalence of obesity (between 12.8% and 20.4%) found in this present study was within reasonable range of the reported range of 12.28% (Abdelkarim *et al.*, 2017) and 20.1% (Talat & El Shahat, 2016) among Egyptian children and adolescents, but lower than the 25% prevalence rate reported by Ginsburg *et al*. (2013) for children and adolescents from Johannesburg. The prevalence of underweight of between 10.6% and 16.3% in this study was within the range of the 3.6% to 21.6%

for Korean children and adolescents reported by Kim (2012). Our findings showed that the prevalence of obesity in South African children is no different from that of children and adolescents across the world. The rise in the prevalence of obesity also reaffirms previous findings that overweight and obesity are on the rise among South African children and adolescents (Pienaar, 2015; Toriola *et al*., 2015).

Studies have reported that LPA, sedentary behaviour and uncontrolled nutritional habits are some of the important risk factors of overweight and obesity (Berenson, 2002; Onywera *et al*., 2012). Although the assessment of the nutritional habits of adolescents in our sample was beyond the scope of this study, there is a possibility that their influence could have an impact on the relationships in this research. The inclusion of nutritional data may give different results.

Conclusion

There was no significant relationship between changes in body composition, PA and TV watching time. For anthropometric measurements, more specially %BF and BMI show relatively increase, and with time spent watching TV also increasing over a period of time. Changes in TV watching time are non-significantly, but positively associated with body composition variables (BMI, %BF, and sum of skinfolds) independent of PA, and the changes in PA are not related to changes in body composition. Indicators of obesity (BMI, %BF, and sum of skinfolds) were found to be higher among the girls compared to the boys. Boys' participation in MPA and VPA was higher than girls and there was no difference in TV watching time for either boys or girls. The rising tendency of BMI and %BF, and a decline in MPA and VPA levels among the girls could expose them to obesity and the risks of CVD in the future if no preventive measures are taken. Given the public health implications of this results, urgent strategic intervention programmes aimed and the reduction of fatness and TV watching are needed.

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Conflict of interests

The authors declare no conflict of interest

Authors' contributions

VM. (North-West University) is a Ph.D student and contributed to the development of research objectives, data input, analysis, and write-up of the article.

SC. (North-West University) contributed to the write-up and commented on the final version.

SJM. (North-West University) contributed to data collection, analysis, write-up and commented on the final version.

MAM. (North-West University) is the principal investigator of the PAHL study, and was responsible for the overall research design, all logistics and application for funding for the study, and contributed to data analysis and write-up, and commented on the final version.

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CHAPTER 5

THE TWO-YEAR LONGITUDINAL RELATIONSHIPS BETWEEN CHANGES IN BODY COMPOSITION AND CHANGES IN SELECTED METABOLIC RISK FACTORS (ABDOMINAL OBESITY AND BLOOD PRESSURE) AMONG ADOLESCENTS FROM POTCHEFSTROOM IN THE NORTH WEST PROVINCE OF SOUTH AFRICA

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The two-year longitudinal relationships between changes in body composition and changes in selected metabolic risk factors (abdominal obesity and blood pressure) among adolescents from Potchefstroom in the North West Province of South Africa.

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5.1 ABSTRACT

Background/Objective: Incidents of childhood high blood pressure (BP) are increasing worldwide. The current study examined the longitudinal relationship between changes in body composition (i.e. body mass index (BMI), waist circumference (WC) and percentage body fat (%BF)) and selected metabolic risk factors (abdominal obesity and BP) among adolescents from the Tlokwe municipality in the North West Province of South Africa.
Materials and Methods: Two hundrend and eighty nin (289) adolescent boys (116) and girls (173) aged 14 to 16 year old (mean age 14.9±0.76 years) participated in the study. Body composition was measured following the International Society of the Advancement of Kinanthropometry (ISAK) standard procedures. BMI was calculated as height in meters squared divided by weight in kilogram (m^2/kg). Abdominal obesity was determined using WC measurements and resting BP was determined by Omron MIT Elite Plus.
Results: Significant changes were found for stature, BMI, body mass, WC, and systolic BP (SBP)and diastolic BP (DBP)BP ($p<0.05$). BMI for the total group was significant and positively related to abdominal obesity in 2012 ($r=0.55$; $p<0.01$) and in 2013 ($r=0.77$; $p<0.01$) and to SBP ($r=0.26$; $p<0.05$) in 2012 and ($r=0.17$; $p=0.43$) in 2013. BMI among the boys was significant and positively related to abdominal obesity in 2012 ($r=0.83$; $p<0.01$), and 2013 ($r=0.91$; $p<0.01$); and positive but non-significantly related to BP. For the girls, BMI was significantly and positively related to abdominal obesity ($r=0.49$; $p<0.01$) and to SBP ($r=0.32$; $p=0.05$) in 2012.
Conclusions: BMI was positively related to BP and abdominal obesity. Relatively high BMI and abdominal obesity significantly increase the likelihood of elevated BP over a period of time. BMI is a predictor of abdominal obesity in boys while in girls, BMI is a predictor of both abdominal obesity and SBP.

Keywords: Body composition, metabolic risk factors, abdominal obesity, blood pressure, adolescents.

5.2 INTRODUCTION

Globally, both obesity and hypertension are reported to be prevalent in childhood and adolescence. The rising prevalence worldwide of obesity was noted at an estimate of 47.1% in the past decades from 1980–2013 among children and adolescents [1] while the prevalence of prehypertension increased from 7.7% to 10% in children aged 8–17 years [2]. The fastest increase in the prevalence of both obesity and hypertension is noticeable among low- and middle-income countries that are undergoing economic transition and whose health delivery systems are weak, such as countries in Africa and Asia [3].

The Medical Research Council of South Africa revealed that over 17% of South African children aged between one and nine years living in urban areas are obese or overweight. The first South African National Health and Nutrition Examination Survey (NHANES 1) documented a combined overweight and obesity prevalence of 13.5% for South African children aged 6–14 years [4]. This is higher than the global prevalence of 10% in school children [5] but lower than the reported levels in the USA (18% for obesity and 32.6% for combined overweight and obesity) for children aged 6–11 years (2009–2010) [6]. According to the 2008 National Income Dynamics Study in South Africa [7], 11% of males aged 15–24 (compared to 4% in the 1998 South Africa Demographic and Health Survey, SADHS) and 20% of males aged 25–34 (compared to 10% in 1998 SADHS) had hypertension. In females, 12% of 15–24-year olds (compared to 7% in 1998 SADHS) and 24% of 25– 34-year olds (compared to 15% in 1998 SADHS) had hypertension. A study reported prevalence rates ranging from 9.2 to 16.4 % for prehypertension and 8.4 to 24.4 % for hypertension among children and adolescents residing in urban areas [8].

Studies have reported a relationship between body mass index (BMI), body size and elevated blood pressure (BP) in children and adolescents [9, 10]. The relationship was shown to be positive and stronger mostly among obese children [10, 11, 12, 13]. Longitudinal studies have demonstrated that children with higher BMI and waist circumference (WC) changed from initially normal (baseline values) to higher BP values at follow-up [2, 10]. In a systematic review of 51 studies [14], it was reported that an increase in BMI was largely associated with the prevalence of elevated BP; being six times higher in obese children and adolescents than those of normal weight.

Total body obesity and central obesity (also known as abdominal obesity) are associated with an increased risk of noncommunicable diseases (NCDs) such as cardiovascular diseases (CVDs) and some forms of cancer [15]. Arguably, Shen et al. [16] indicated that the metabolic risk associated with obesity is closely correlated with a central rather than peripheral fat pattern.

In spite of this, there is a paucity of information in terms of the longitudinal relationship between changes in body composition and metabolic risk factors among South Africa adolescents. The purpose

of the study, therefore, was to determine the longitudinal relationship between changes in body composition and selected metabolic risk factors (abdominal obesity and BP) among adolescents from the Tlokwe municipality in the North West Province of South Africa.

5.3 METHODOLOGY

Design

The present study was part of the Physical Activity and Health Longitudinal Study (PAHLS, 2010–2014), whose main objective was to evaluate the development of physical activity (PA) and determinants of health risk factors among 14-year old high school adolescents in Tlokwe municipality in the North West Province, South Africa, over a period of five years [17]. For the purpose of this study, cross-sectional and longitudinal data collected from 2011 to 2013 were used to determine the longitudinal relationship between changes in body composition and selected metabolic risk factors (abdominal obesity and BP) among the adolescents.

Permission was granted by the District Manager of the Department of Basic Education in Potchefstroom, North West Province before the commencement of data collection process. Written informed consent was obtained from the school authorities, and parents and the learners of the participating schools. Clearance by the Ethics Committee of North-West University, Potchefstroom campus (Ethics number: NWU-0058-01-A1) was granted.

Participants

Two hundred and eighty-nine (289) adolescent boys (116) and girls (173) were selected from six out of eight high schools. Of the six high schools, two were from the Central Business District (CBD) comprised of mostly adolescents from high socio-economic families, and four schools were from the township areas comprising adolescents from low socio-economic families. The mean age of the selected learners was 14.9±0.76 years at baseline measurement in 2011, 15.6±0.77 years in 2012 and 16.4±0.78 years in 2013. School records, as well as participants' birth clinic cards, were used to establish the age of the participants in the study. Detailed information concerning the participants and methods of data collection have been published elsewhere [17].

Anthropometric and body composition measurements: Stature, body mass, skinfolds thickness (triceps and subscapular skinfolds), and waist circumference (WC) and hip circumference were measured using the standard procedures described by ISAK [18]. Waist-to-height ratio (WHtR) was calculated as waist divided by stature (waist/stature (cm)). Body mass index (BMI) was calculated as body mass divided by stature square (kg/m^2). Subsequently, age-specific BMI for children was used to determine the following categories: overweight (BMI of 25 and above), normal weight (BMI between

17.5 and 24.9) and underweight (BMI <17.5), respectively [19]. Percentage body fat (%BF) was calculated from subscapular and triceps skinfolds (mm) measurements using Slaughter et al.'s [20] equation which has been internationally recommended for its use in children from different settings. All anthropometric sites were measured twice according to standard procedures by Level 2 ISAK certified anthropometrists.

Metabolic risk factors

Abdominal obesity

Abdominal obesity was determined using WC measurements. WC was measured at the abdomen at its narrowest point between the lower costal (10^{th} rib) border and the top of the iliac crest, perpendicular to the long axis of the trunk with Lufkin W606PM flexible steel tape according to ISAK [18]. WC values which are age, sex, and ethnicity-specific that fall on the 75^{th} and 90^{th} percentile are important in the identification of children and adolescents at risk for various comorbidities such as CVDs, hyperinsulinemia and type two diabetes mellitus (DM) [21].

Blood pressure (BP) measurement

Measurements were taken on the left arm using the Omron MIT Elite Plus (Omron Healthcare Co., Ltd, Japan). Participants were asked to lie down and rest for five minutes before BP measurements were taken, talking was not permitted during the resting period, nor when the BP measurement was being taken. The average measurement from two separate measurements at least five minutes apart were used in the analysis. A measurement of systolic blood pressure (SBP) >130 millimetre of mercury (mmHg) and diastolic blood pressure (DBP) >85 mmHg was classified as abnormal according to the International Diabetes Federation (IDF) cut point, and SBP $\geq 90^{th}$ percentile for the whole population is considered abnormal according to the National Cholesterol Education Program/Adult Treatment Panel III (NCEP/ATP III) criteria [22].

Statistical analyses

The frequency for percentages (%) for categorical variables was calculated. Analysis of variance (ANOVA) for repeated measures was calculated to determine the changes in anthropometric measures and body composition as well as changes in BP. Paired sample t-test was calculated to determine the mean changes of all the measurement points. Effect size (partial eta square (ηp^2)) was used to determine the magnitude of changes in three sets of measurement points (i.e. Test one (T1), test two (T2) and Test three (T3)). Partial *E*ta-squared of ANOVA are in agreement with Cohen's rule of thumb whereby values of ηp^2 are interpreted as follows: = 0.2, 0.5 and 0.8 were regarded as small, medium and large effects, respectively. Partial correlation coefficients adjusted for the first measurement values and age

were calculated to determine the two-year longitudinal relationship between changes in body composition and changes in selected metabolic risk factors (i.e. abdominal obesity and BP). Data analyses for all the variables were calculated using the Statistical Package for Social Sciences (SPSS) version 25.0 programme and the level of significance was set at $p \leq 0.05$.

5.4 RESULTS

For the total group, the results show developmental growth in terms of body stature and body mass with moderate effect size, with significant differences between boys and girls (Table 1). The effect size for WHtR, SBP, and DBP was low. Mean changes for stature from first measurement (T1) to second measurement (T2) for the total group was 2.16 cm and 0.76 cm for year two to year three. Changes in stature for the T2 and third measurement points (T3) in boys showed a significant ($p<0.001$) increase of 3.75 cm and 2.7 cm respectively, compared to the girls (0.62 cm and 1 cm). Body mass showed an increase of 3.61 kg from T1 to T2, and 2.54 kg from T2 to T3 for the total group; boys presented significantly ($p<0.001$) greater changes 4.84 kg (T1 and T2) compared to girls 2.42 kg, and 3.26 kg (T2 and T3) compared to girls 1.86kg. With regard to changes in BMI for the total group, increases of 0.82 kg from T1 to T2 and 0.48 kg from T2 to T3 were observed. Changes in BMI for the T2 and T3 measurement points in boys showed a significant ($p=0.01$) increase of 0.83 kg (compared to 0.81 kg for girls) and 0.48 kg (compared to 0.46 for girls). All measures of body composition changes over time were moderate.

Increases of 1.15 cm in WC from T1 to T2, and 1.07 cm from T2 to T3 were found for the total group, with boys showing a significant ($p=0.01$) increase of 2.18 cm from T1 to T2 (compared to 0.17 cm for girls) and 1.28 cm from T2 to T3 (compared to 0.88 cm for girls). In terms of BP, mean change in SBP for the total group T1 one to T2 was 4.35 mmHg, and 1.46 mmHg from T2 to T3. Boys presented significantly ($p<0.001$) greater mean changes in the T2 and T3 measurement points (5.13 mmHg and 2.34 mmHg, compared to 3.66 mmHg and 0.47mmHg for girls respectively). Mean changes for DBP from T1 to T2 for the total group was 1 mmHg and for T2 to T3 was 3.96 mmHg. Changes from T1 to T2 were significantly greater in boys (1.93mmHg) compared to girls (1.7mmHg), while in T2 and T3, girls presented significantly ($p<0.001$) greater changes (4.98 mmHg) compared to boys (2.81 mmHg). The magnitude of changes in BP was small over a period of time.

Table 1 Participant characteristics (mean, standard deviation (SD), partial *E*ta square and p-values) for the total group and by gender

	Total group (n=186)				**Boys (n=81)**			**Girls (n=105)**				
	T1 (2011)	**T2 (2012)**	**T3 (2013)**		**T1 (2011)**	**T2 (2012)**	**T3 (2013)**	**T1 (2011)**	**T2 (2012)**	**T3 (2013)**		
Variables	**Mean± SD**	**Mean± SD**	**Mean± SD**	**Partial Eta Square**	**Mean± SD**	**Mean± SD**	**Mean± SD**	**Mean± SD**	**Mean± SD**	**Mean± SD**	**Partial Eta Square**	**P-value of the gender differences**
Stature (cm)	161.48±8.74	163.64±9.16	165.49±9.62	.45	164.80±9.07	168.55±8.34	171.25±8.17	158.25±7.09	158.87±7.22	159.87±7.36	.52	<0.001
Body mass (kg)	54.51±13.18	58.12±13.48	60.66±14.00	.52	54.46±12.03	59.30±13.38	62.56±14.03	54.56±14.27	56.98±13.56	58.84±13.81	.55	<0.001
BMI (kg/m^2)	20.79±4.22	21.61±4.23	22.08±4.34	.32	19.86±2.99	20.69±3.34	21.17±3.52	21.68±4.99	22.49±4.80	22.95±4.88	.32	0.01
WC (cm)	67.89±8.18	69.04±8.42	70.11±8.74	.22	67.63±6.87	69.81±7.74	71.09±8.34	68.13±9.31	68.30±9.01	69.18±9.06	.24	0.01
WHtR	.42±.04	.42±.04	.42±.05	.02	.41±.03	.41±.03	.41±.04	.43±.05	.43±.05	.43±.05	.01	0.46
SBP (mmHg)	103.45±10.51	107.80±12.42	109.26±9.73	.21	106.55±11.68	111.68±12.52	112.15±7.93	100.70±8.52	104.36±11.33	106.70±10.49	.10	<0.001
DBP (mmHg)	66.70±8.35	67.70±8.88	71.66±8.11	.12	68.30±9.24	70.23±9.73	73.04±8.02	65.29±7.23	65.46±7.42	70.44±8.04	.20	<0.001

p<0.001; significant difference between boys and girls)

Significant ($p \leq 0.05$) high developmental tracking correlation coefficients were found for stature, body mass, BMI, WHtR and WC for the total group and for boys and girls (Table 2). With regard to BP, SBP showed a low significant development between the T1 and T2 measurement point and (r=.39; p=0.01) as well as between the T2 and T3 measurement points (r=.23; p=0.01) for the total group. In terms of gender, significant development was found between the T1 and T2 measurement points in boys, while in girls, significant development was found at the T2 and T3 measurement points for both SBP and DBP.

Table 2 Correlation coefficients of the T1 measurements with the T2 and T3 measurements

	Total group		Boys		Girls	
	T2 (2012)	T3 (2013)	T2 (2012)	T3 (2013)	T2 (2012)	T3 (2013)
	r	R	R	r	r	R
Stature (cm)	.90**	.88**	.91**	.87**	.86**	.93**
Body mass (kg)	.93**	.90**	.91**	.82**	.93**	.94**
BMI (kg/m^2)	.92**	.88**	.91**	.84**	.92**	.91**
WC (cm)	.89**	.87**	.87**	.80**	.89**	.90**
WHtR	.86**	.83	.76**	.69**	.90**	.83**
SBP (mmHg)	.39**	.23**	.43**	-.05	.21	.38**
DBP (mmHg)	.15	.16	.37**	.08	.04	.24*

***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

In the total group and for boys and girls at the T1 measurement point, pre-hypertension was 5% (Figure 1). At T2 measurement point, prehypertension showed an increase of 3% for the total group with boys being presented with high percentage scores (14%) in 2012. An increase of 2% from T2 to T3 was observed with boys been presented with high percentage (18%) score of pre-hypertension compared to the girls. While in girls, pre-hypertension decreased 1% in 2012 and remain unchanged at T3.

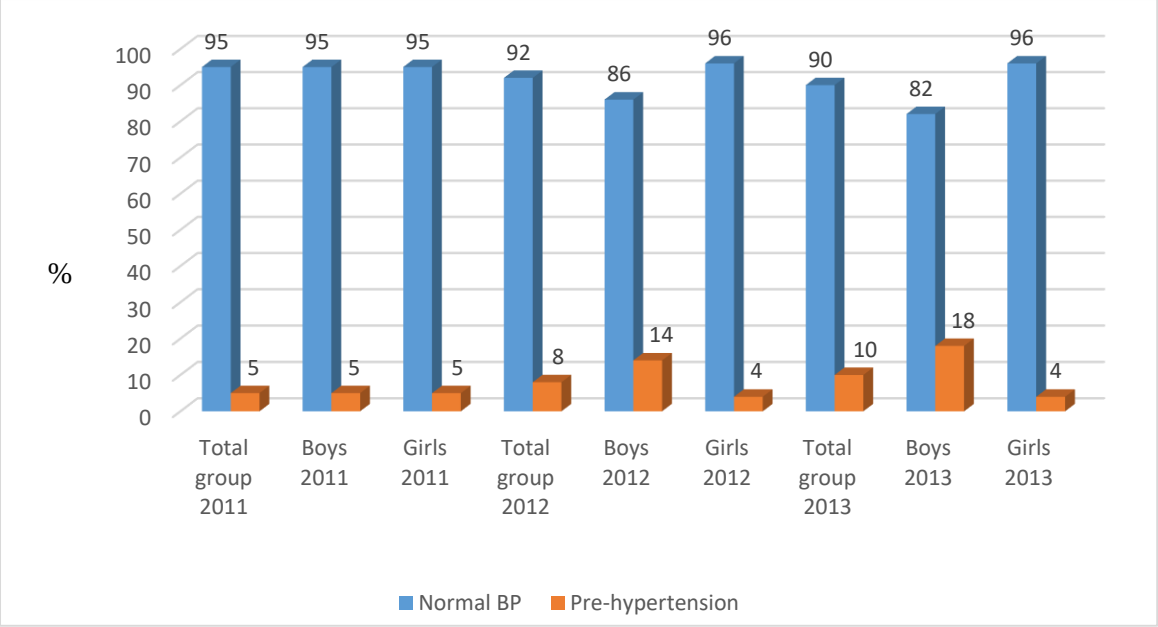

Figure 1 Percentage (%) scores of BMI categories distribution of the participants

Overweight at the first measurement point was 13% for the total group, with girls being more overweight (18%) compared to the boys (6.1%) (Figure 2). Underweight was 17% for the total group with boys (21.4%) being more underweight than the girls (14%). There was an increase in overweight and decrease of underweight over the three measurement points, with girls being more overweight and boys more underweight over the three points.

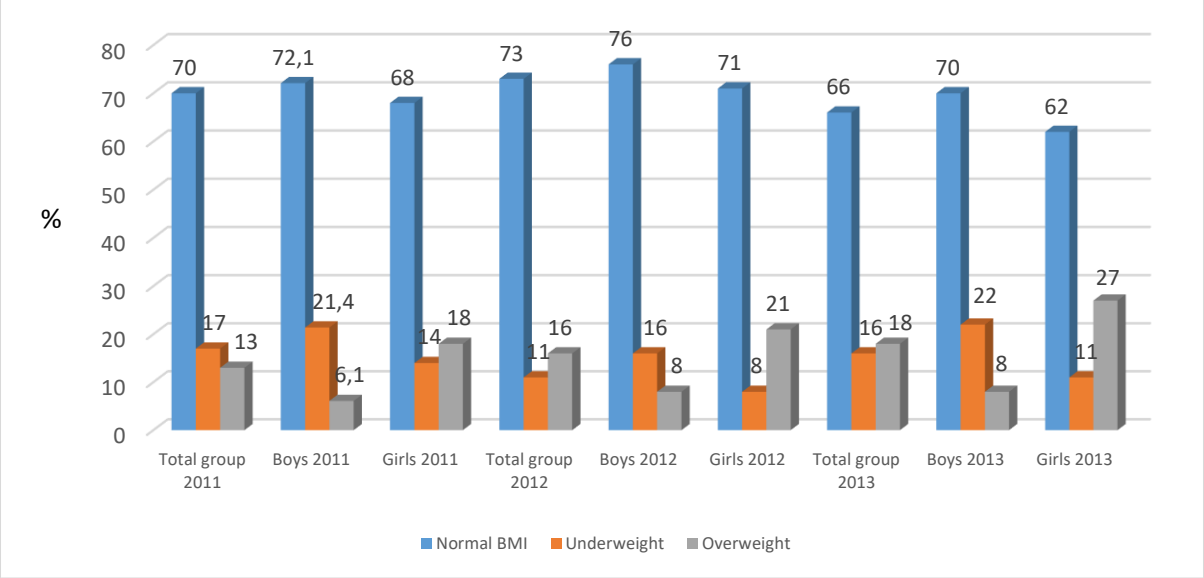

Figure 2 Percentage score (%) of prehypertension of the participants

Table 3 Correlation matrix of the three-point measurements of anthropometry, body composition and BP for the total group

		ΔBMI T2	**ΔWHtR T2**	**ΔBMI T3**	**ΔWHtR T3**	**ΔWC T2**	**ΔWC T3**	**ΔSystolic T2**	**ΔDiastolic T2**	**ΔSystolic T3**	**ΔDiastolic T3**
BMI T2	r	-	.59	.82	.59	.55	.52	.26	.09	.08	.04
	p	.	.00	.00	.00	.00	.00	.00	.26	.33	.65
WHtR T2	r	.59	-	.49	.64	.92	.59	.10	.15	.11	.05
	p	.00	.	.00	.00	.00	.00	.23	.07	.19	.59
BMI T3	r	.82	.49	-	.83	.46	.77	.19	.06	.17	.07
	p	.00	.00	.	.00	.00	.00	.03	.52	.04	.43
WHtR T3	r	.59	.64	.83	-	.58	.90	.05	.06	.14	.09
	p	.00	.00	.00	.	.00	.00	.52	.49	.09	.24

Adjusted for age, first measurements of BMI, WHtR, SBP and DBP; p= p-value of the significant

The correlation matrix showed that BMI for the total group was significant and positively related to WC, WHtR and SBP in the second and third measurements after adjusting for age and baseline measurements of BMI, WHtR, and SBP and DBP (Table 3).

Table 4 Correlation matrix of the three-point measurements of anthropometry, body composition and BP for the boys

		ΔBMI T2	**ΔWHtR T2**	**ΔBMI T3**	**ΔWHtR T3**	**ΔWC T2**	**ΔWC T3**	**ΔSystolic T2**	**ΔDiastolic T2**	**ΔSystolic T3**	**ΔDiastolic T3**
BMI T2	r	-	.80	.84	.73	.83	.75	.11	.09	.14	.02
	p	.	.00	.00	.00	.00	.00	.37	.44	.27	.89
WHtR T2	r	.80	-	.70	.76	.90	.70	.09	.09	.07	.02
	p	.00	.	.00	.00	.00	.00	.49	.46	.57	.89
BMI T3	r	.84	.70	-	.91	.72	.91	.06	.01	.13	.04
	p	.00	.00	.	.00	.00	.00	.61	.95	.30	.73
WHtR T3	r	.73	.76	.91	-	.69	.91	-.01	-.02	.05	.01
	p	.00	.00	.00	.	.00	.00	.92	.86	.70	.92

Adjusted for age, first measurements of BMI, WHtR, systolic and diastolic BP; p= p-value of the significant

When data were analysed separately according to gender, BMI among the boys (Table 4), was significantly positively related to WC and WHtR ($p<0.01$) at all measurement points. The relationship between BMI and BP measurements among the boys was in a positive direction although it was not statistically significant.

Table 5 Correlation matrix of the three-point measurements of anthropometry, body composition and BP for the girls

		ΔBMI T2	**ΔWHtR T2**	**ΔBMI T3**	**ΔWHtR T3**	**ΔWC T2**	**ΔWC T3**	**ΔSystolic T2**	**ΔDiastolic T2**	**ΔSystolic T3**	**ΔDiastolic T3**
BMI T2	r	-	.51	.81	.52	.50	.52	.33	.14	.07	.02
	p	-	.00	.00	.00	.00	.00	.01	.24	.57	.87
WHtR T2	r	.51	-	.39	.57	.97	.54	.06	.18	.11	.02
	p	.00	-	.00	.00	.00	.00	.65	.14	.39	.84
BMI T3	r	.81	.39	-	.75	.37	.75	.19	.06	.22	.04
	p	.00	.00	-	.00	.00	.00	.12	.65	.06	.76
WHtR T3	r	.52	.57	.75	-	.56	.97	.02	.11	.23	.14
	p	.00	.00	.00	-	.00	.00	.85	.35	.05	.24

Adjusted for age, first measurements of BMI, WHtR, SBP and DBP; p= p-value of the significant

Among the girls, (Table 5), BMI was significantly and positively related to WC and WHtR ($p<0.01$) at all measurement points after adjusting for age and baseline measurements. A positive significant relationship was also noted between BMI and SBP at T2 measurement point ($p=0.01$), while at T3 measurement point a borderline relationship was found; and WHtR was significantly related to SBP ($p=0.05$) in 2013.

5.5 DISCUSSION

The purpose of our study was to determine the two-year longitudinal relationship between changes in body composition and selected metabolic risk factors in 14-year old adolescents from Potchefstroom in the North West Province of South Africa. The major findings of this study revealed that for the total group, BMI was significantly positively related to abdominal obesity and SBP at all points of measurement. Gender differences in these relationships indicated that in boys, BMI and abdominal obesity were significantly and positively related, while BMI and BP were not significantly related (although the relationship was in a positive direction). In girls, BMI and abdominal obesity were positively correlated with SBP.

Our findings are consistent with studies from schools in Mexico City [23], Indianapolis [24], Chinese children [12, 25], whereby strong positive relationships between obesity and high BP are reported. Given the observed current findings and revealed relationships in adults, strategic intervention to prevent the development of cardiometabolic outcomes is needed.

The risk of hypertension increased as the odds ratio of overweight and obesity increased [26]. Our study findings showed that an increase in BMI predicts an increase in both abdominal obesity and BP levels. In this regard, maintaining a normal body weight could be one of the effective measures for preventing the development of hypertension.

A lack of significant relationship between BMI and BP in boys was also reported among the Chinese children [12]. In our study, the non-significant relationship between BMI and BP among the boys compared to the girls could be explained by a small increase in BMI among the boys compared to the girls throughout the measurement period.

The prevalence of overweight for the total sample was 13%, with girls being more overweight (18%) compared to the boys (14%). The prevalence of overweight in this study was lower than that of adolescents in the Grand Canary Islands (29.1%) [27] and the Balearic Islands (24.7%) [28], but greater than the 11.3% of adolescents in the CASPIAN study (Iran) [29] and (4.4%) of Chinese adolescents [26]. The prevalence of underweight was 17% for the total sample with boys (21.4%) being more underweight than the girls (14%). This was greater than the 13.9% (total sample), 8.1% (boys) and 5.7% (girls) reported by Li et al. [26] although there was consistency in boys being more underweight than girls in both samples. The tendency of boys for greater WC than girls in our study agrees with the

findings of DeMoraes et al. [30], who reported a higher prevalence of abdominal obesity among boys than the girls.

High developmental tracking correlation coefficients found in this study for body mass, BMI, WHtR and WC showed that upward trends of obesity for South African children and adolescents are no different to other children across the world. It is widely reported that childhood obesity is on the rise globally [3, 31, 32]. Motorised transportation, low physical activity (LPA) and spending more time in sedentary behaviour (although not included in the analyses of the current study) may be blamed for the high prevalence of overweight and obesity among the youth worldwide [1, 31, 33]. The increase in indices of adiposity found in this study also confirms the findings from earlier studies that childhood obesity is on the rise among South African children and adolescents [34, 35].

Elevated BP during childhood and adolescence is associated with increased cardiovascular risk in later life and the development of early pathological signs of atherosclerosis [10]. Boys presented with high percentage scores of prehypertension (14% in 2012 and 18% in 2013) compared to a respective 4% in girls. The greater prehypertension score in boys could be explained by a greater increase in WC among the boys at all measurement points compared to the girls. Both higher BMI and WC are risk factors of high BP [36]. If the situation remains unchecked, both boys and girls in this sample could be at risk of developing hypertension in later life.

The study was conducted on a group of adolescent boys and girls from selected schools in Potchefstroom town; the results of the study may have differed if the study had used a larger sample of adolescents. It has been found that some of the risk factors of overweight and obesity include LPA, sedentary behaviour and poor nutritional behaviour [28, 32]. In this study, PA and nutritional behaviour of adolescents were not assessed although these factors could have influenced the relationship between changes in body composition and selected metabolic risk factors in this research.

Conclusion

In conclusion, it was found that overweight with a moderate magnitude was on the rise among adolescents living in the Tlokwe Local municipality of Potchefstroom. Both high BMI and abdominal obesity significantly increase the likelihood of high BP over a period of time. BMI is a predictor of abdominal obesity in boys while in girls BMI is a predictor of both abdominal obesity and (high) BP. The rising trend of BMI, WC, and SBP could put the adolescents at risk of developing CVDs later in life.

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the final version. S.J.M. (NW-University), contributed to data collection, analysis, write-up and commented on the final version. M.A.M. (North-West University), is the Principal Investigator of the PAHL study, and was responsible for the overall research design all logistics and application for funding for the study and contributed to data analysis, write-up and commented on the final version.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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CHAPTER 6:
SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

6.1 SUMMARY

Childhood obesity is a serious global public health concern (WHO, 2012). The World Health Organization (WHO) reported that more than 28 million deaths occurred globally in 2012 due to noncommunicable diseases (NCDs) and of these deaths, cardiovascular diseases (CVDs) was the leading cause responsible for 46.2% of these. It was further reported that the number of overweight and obese children increased from 32 million to 42 million between 1990 and 2013 globally (WHO, 2014). In Africa, the number of overweight and obese children increased from four million to nine million during the same period. The 2014 World Health Assembly projected that more than 70 million children will be overweight and obese by the year 2025 globally if the situation remains unchecked.

Obesity is assumed to be an outcome of several health risk factors such as physical inactivity (PI) and a sedentary lifestyle, such as television (TV) watching and engaging in computer related activities, as well as uncontrolled nutritional habits (Berenson, 2002; Ellulu *et al*., 2014; Draper *et al*., 2014). Obesity (particularly central/abdominal) is a major metabolic risk factor of CVD (Després, 2012) and has been found to coexist with other metabolic risk factors such as high blood pressure (BP), (Han & Lean, 2016), type two diabetes mellitus (DM) and insulin resistance (Eckel *et al*., 2011), impaired glucose tolerance (IGT) (Rivers *et al*., 2014), and dyslipidaemia (Reuter *et al*., 2016). Most of these risk factors manifest at adulthood but they originate in the childhood and adolescence stages (Berenson, 2002).

Studies on South African children and adolescents from both rural (Monyeki *et al*., 2005:877; Moselakgomo *et al*., 2015:730) and urban areas (Malan *et al.*, 2008:325; Micklesfield *et al.,* 2014:14; Pienaar, 2015:2; Pedro *et al*., 2016:194) reported rising trends of overweight and obesity. An increased prevalence of other metabolic risk factors like hypertension, impaired glucose tolerance (IGT) and dyslipidaemia among this population have been reported (Puoane *et al*., 2002:1041; Vorster *et al*., 2007:283; Zeelie *et al.,* 2010:285; Goon *et al*., 2013:490; Kagura *et al*., 2015:1; Awotidebe *et al.,* 2015:3; Sekokotla *et al*., 2017:134). Studies have also revealed that physical activity (PA) levels are declining among South African children and adolescents (Reddy *et al*., 2003:64; Micklesfield *et al*., 2014:14; Reddy *et al*., 2012:262; Pienaar, 2015:2; Uys *et al*., 2016:265). For example, the South African National Youth Risk Behaviour Survey revealed that 37.5% of South African adolescent learners are insufficiently physically active (Reddy *et al*., 2003:63–66), while the Healthy Active Kids South Africa (HAKSA) 2014 Report Card revealed that only 50% of children were meeting the recommendations for daily PA.

Similarly, the 2016 Report Card on PA for children and youth (Uys *et al*., 2016:265) showed that South African children are not meeting the recommended guidelines of two hours or less daily screen time, specifically due to extreme use of social media and cell phones. The level of PA among South African youth varies with ethnicity (Reddy *et al.,* 2003:64; Engelbrecht *et al*., 2004:44; Malhotra *et al*., 2008:315; Wushe *et al*., 2014:2), with blacks, particularly in urban settings, reportedly being insufficiently physically active compared to whites. One of the studies (Engelbrecht *et al*., 2004:44) found that in the North West Province Indian girls (94%) were the least active, followed by coloured girls (87.5%), black girls (72.9%) and white girls (61%). Children and adolescents from farming- (Prinsloo & Pienaar, 2003:151) and rural areas (Monyeki *et al*., 2005b:58; Moselakgomo *et al*., 2014:347) are more physically active compared to those from urban areas.

Studies have shown that there is an inverse relationship between body composition, PA and metabolic risk factors of CVD. High levels of PA and cardiorespiratory fitness were associated with healthy metabolic profiles among children and adults (Steele *et al*., 2008:342; Salonen *et al*., 2015:1) and reduce the prevalence of metabolic risk factors (Warburton *et al*., 2006:801; Moreira *et al*., 2011:2; Barret *et al*., 2014:1). Regular PA delays the onset of obesity and type two DM (CDC, 2009) by increasing insulin sensitivity and improving blood glucose utilisation by skeletal muscles, as well as reducing the accumulation of visceral fat and triglycerides (Laaksonen *et al*., 2002:1612).

Research has also found that moderate vigorous physical activity (MVPA) lowers the prevalence of risk factors for breast cancer by reducing the level of the hormone oestrogen which is thought to accelerate the development of breast and cervical cancer among women (World Cancer Research Fund, 2007:10; Suba, 2013:158). Many studies have analysed the association between PA, obesity and sedentary behaviour mainly characterised by TV watching (Proctor *et al*., 2003:830; Must & Tybor, 2005; Tremblay *et al*., 2011; French *et al*., 2012; Liao *et al.,* 2013:588; Staiano *et al.,* 2013:40; Roseik *et al.,* 2015:9408). In common, these studies noted that PA is lower during TV watching time, and low levels of PA combined with prolonged TV watching time among children is linked with an increase in the indices of overweight and obesity. Children who watch TV more than three hours per day have a high risk of developing obesity compared to those who watch for less than three hours daily (Dietz & Gortmaker, 1985:807; Tammelin, 2009:284; Melkevik *et al*. 2015:5). Although evidence suggests the existence of an association between PA, obesity and TV watching time, the evidence seems inconclusive as some studies (Tuckers, 1986; Robinson *et al*., 1993; Durant *et al*., 1994; Hanley *et al*., 2000) found no association and/or a weak relationship between these variables.

It is against this background that the current study was conducted to explore the longitudinal changes in body composition, PA and selected metabolic risk factors, in order to determine the relationship between longitudinal changes in body composition, PA and TV watching time; and also to determine the relationship between longitudinal changes in body composition, PA and selected metabolic risk

factors among adolescent high school adolescents within the Tlokwe municipality in the Potchefstroom area of the North West Province of South Africa.

This chapter ends with conclusions. Chapters three, four and five are each presented in the form of a research article from which the conclusions drawn as outlined in this chapter (6) are in accordance with the hypothesis set in chapter one.

6.2 CONCLUSIONS

Hypothesis one stated that there will be significant longitudinal changes in body composition, PA and selected metabolic risk factors (abdominal obesity and BP) among adolescents. Hypothesis two was that there will be a significant positive relationship between two-year longitudinal changes in body composition, PA and TV watching time among adolescents while hypothesis three stated that there will be a significant positive relationship between two-year longitudinal changes in body composition and selected metabolic risk factors (abdominal obesity and BP).

(i) The results confirmed **Hypothesis one**: that there will be significant longitudinal changes in body composition, PA and selected metabolic risk factors (abdominal obesity and BP) among adolescents. Significant changes were noted in body composition variables (weight, height, BMI, %BF and the SSF), PA (moderate-, vigorous- and total PA) as well as in metabolic risk factors (WC, DBP, and SBP) over the measurement period of two years. The incidence of overweight and obesity and PI significantly increased, especially among the girls compared to the boys from 2011 to 2013 measurement period. Therefore, Hypothesis one is accepted.

(ii) The results of the study showed that there was no significant ($p>0.05$) relationship between changes in body composition, PA and TV watching time. Changes in TV watching time and BMI were both non-significant and negatively related to changes in MPA and VPA, and the effects of changes were high for BMI and small for MVPA and VPA. After adjusting for age, the results indicated a significant negative relationship between BMI and TPA among the boys ($p=0.02$), and between the sum of skinfolds and MPA among the girls ($p=0.04$). In light of these results, **Hypothesis two** which stated that there will be a significant positive relationship between two-year longitudinal changes in body composition, PA and TV watching time among adolescents, therefore, was rejected.

(iii) With regard to **Hypothesis three,** proposing that significant positive relationships between two-year longitudinal changes in body composition and selected metabolic risk factors (abdominal obesity and BP) will exist, the results showed that BMI was significant and positively related to BP and WC. Therefore, **Hypothesis** threewas accepted.

6.3 LIMITATIONS

The following limitations should be considered in interpreting the findings of this study:

(i) The study was conducted in six high schools in the Tlokwe Local municipality of Potchefstroom town, therefore the findings of this study are limited to the adolescents from the participating schools and cannot be generalised as a reflection of the PA, body composition, metabolic risk factors and TV watching time of all learners in the Tlokwe municipality of Potchefstroom, the North West Province nor South Africa as a whole. Such generalisation would require a more representative sample of adolescents from schools in the North West Province and other provinces around South Africa.

(ii) The study is part of a larger study; the Physical Activity and Health Longitudinal Study (PAHLS) whose main objective was to assess the development of PA and determinants of health risks and factors affecting the participation of 14-year old adolescents in sport and recreational activities. This current study used data collected over two years only, thus the findings may have been different if the study had been conducted over a longer period given the fact that other studies have confirmed that changes in body composition associated with PA and sedentary behaviour became more apparent over a longer follow-up period (Robinson, 2001). In addition, the study was conducted on a group of adolescent boys and girls from selected schools in Potchefstroom town; the results of the study may have differed if the study had used a larger sample of adolescents.

(iii) Several studies have reported that the important risk factors of overweight and obesity include LPA, sedentary behaviour and uncontrolled nutritional behaviour, among others (Berenson, 2002; Onywera *et al*., 2012). The nutritional habits of adolescents in this study were not assessed as it was beyond the scope of the study. However, the possible influence of nutrition on the relationship between changes in body composition, PA and metabolic risk factors in this research cannot be overruled.

(iv) It is well known that sedentary behaviour is explained in many dimensions such as reading, passive transportation, playing video games, computer use, playing board games, driving a car, sitting and watching TV and others. In this study, TV watching time was used as the only index of sedentary behaviour. Therefore, the results on overweight and obesity of this study may have been influenced by other forms of sedentary behaviour other than TV watching alone.

6.4 RECOMMENDATIONS

The purpose of this study was to determine the two-year longitudinal changes in body composition, PA and TV watching time in relation to selected metabolic risk factors. Based on the findings of the study, the following recommendations can be made:

(i) With regard to the declining PA levels of adolescents, it is important for school authorities to provide enough time and opportunity for adolescents to participate in PA and sport at school. This can be achieved by giving Physical Education (PE) equal importance in the school curriculum to other subjects such as mathematics, English and science. This could also be achieved by providing adequate and safe playing space around the schools so that children can play during break time.

(ii) There is a need for continuous monitoring and profiling of body composition, PA levels, sedentary behaviour, and nutritional status as well as metabolic disease risk of children so that any deviation from normal growth standards can be easily identified and corrected. Continuous monitoring of body composition and metabolic disease risk can also help to quickly identify children who are at risk of developing metabolic-related illnesses such that early intervention strategies can be implemented to reverse or reduce the risk.

(iii) Future researchers can develop research designs using a bigger sample and develop intervention strategies (based on the findings of the current study) to maximise childhood participation in PA and reduce sedentary behaviour.

(iv) Education and school authorities should use research evidence to guide policy and develop intervention programmes that promote maximum PA participation by youths. The community should strengthen advocacy to reduce sedentary lifestyles such as TV watching time and computer usage, and encourage active play and active transportation among children and adolescents.

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ANNEXURES

APPENDIX A: GUIDELINES FOR AUTHORS

South African Journal for Research in Sport, Physical Education and Recreation

INFORMATION FOR AUTHORS

The *South African Journal for Research in Sport, Physical Education and Recreation* is published by Stellenbosch University. Contributions from the fields of Sport Science, Physical Education, Recreation/Leisure Studies, Exercise Science and Dance Studies will be considered for publication. The articles submitted will be administered by the appropriate Subject Review Editor and evaluated by two or more referees. The decision as to whether a particular article is to be published or not, rests with the Editorial Board.

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Authors are also requested to name three/3 potential referees, of which one/1 must be an *international* referee (the Journal is not bound to use these referees). Complete information regarding the referees (name, surname, e-mail address and telephone numbers) must be provided in the cover letter.

We discourage the practice of parts of one study in different journals. Authors who submit a manuscript from a study of which some data have been or will be published elsewhere, must provide a strong justification in the accompanying letter to the Editor. The justification for not publishing all the data together in one paper must also be motivated in the covering letter.

The author should also ensure that the ***language*** of the manuscript has been ***edited*** thoroughly (English [UK]) by the time of submission. The name, address and telephone number of the person who did the language editing must be provided. Any expenses incurred by the Journal dealing with language editing will be added to the author's page fees.

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Manuscripts must be presented in a format that is compatible with *Microsoft Word for Windows (PC).* Tables, all figures (illustrations, diagrams, etc.) and graphs are regarded as text and must be presented in a format that is compatible with ***Word*** and figures should be ***accessible*** to make any text corrections. Photographs must be presented in *jpg* format.

Original manuscripts must contain the following sections in the following sequence: Title page, Abstract, Introduction, Purpose of Research, Methodology, Results, Discussion, Practical application, Conclusions, Acknowledgements (if applicable) and References.

Title page

The first page of each manuscript should indicate the *title* in English and Afrikaans (will be translated for foreign authors), the *names* (title, first name in full and other initials, surname) of the author(s), the *telephone* numbers (work & home [*& mobile* for local authors]), *facsimile* number, *E-mail* address and the *field of study*. The ***complete mailing address and telephone numbers*** of the corresponding author and the institution (department, university, city, country) where the work was conducted should be provided in full. When more than one author and/or authors from various departments and institutions are involved, the ***[1]author(s***) must be numbered according to their ***[1]department(s).*** If any of the above-mentioned information should change during the review process, please inform the Subject Editor. A ***short title*** of not more than ***45 characters*** (including spaces), should be provided for use as a running heading.

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Each manuscript must be accompanied by an abstract of approximately 150-200 words in English and should be set on a separate page as a SINGLE paragraph (1.5 spacing). A list of three to seven ***key words*** in English is required for indexing purposes and they should be typed below the abstract. Articles in Afrikaans must include an ***additional*** extended ***summary*** (500-1000 words) in English. This summary must start on a new page (just before the reference list) and the English title of the article should be placed at the beginning.

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Start the text on a new page with the title of the article (centred and *without* the names of the authors). Follow the style of the most recent issue of the Journal regarding the use of headings and subheadings. Use only ***one-line space*** after a paragraph. Only make use of ***section breaks*** and not ***page breaks***. The text, as well as the tables and figures, may not be in any other format than ***normal.*** Thus, ***no style sheets*** may be used.

Tables and figures

Tables and figures should be numbered in *Arabic* numerals (1, 2, etc.). Tables require the heading at the *top*, while figures have the legend *below* and both are not included in the cells of the table/figure. ***Note:*** Use the decimal POINT (not the decimal comma). The site where the table or figure should be placed in the text must be indicated clearly in the manuscript. All tables and figures are to be placed *after the reference list* with each on a ***separate page***, always ending with a ***section break***. Any preference for the use of *colour* in the case of figures or photographs must be noted and will be at an *additional cost* to the page tariff.

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References

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Book

WEINBERG, R.S. & GOULD, D. (2011). *Foundations of sport and exercise psychology* (5th ed.). Champaign, IL: Human Kinetics.

Chapter in book

SCHNECK, C.M. (2010). Visual perception. In J. Case-Smith & J.C. O'Brian (Eds.), *Occupational therapy for children* (6th ed.) (pp. 373-403). Maryland Heights, MO: Mosby.

Thesis/Dissertation

SURUJLAL, J. (2004). Human resources management of professional sports coaches in South Africa. Unpublished doctoral dissertation. Johannesburg, South Africa: Rand Afrikaans University.

Proceedings of a conference

HARDMAN, K. & MARSHALL, J. (2001). Worldwide survey on the state and status of physical education in schools. In G. Doll-Tepper & D. Scoretz (Eds.), *World summit on physical education* (pp. 15-37). Proceedings of the "World Summit on Physical Education", 3-5 November 1999. Berlin, Germany: International Council of Sport Science and Physical Education (ICSSPE).

Personal communication/correspondence/interview

BOUKES, P.B. (2015). Personal communication from the Acting Director of Sport at the Nelson Mandela Metropolitan University, Port Elizabeth on 27 February 2015. JACOBS, L. (2015). Personal interview with the Spokesperson of UNICEF, 25 August, Pretoria.

Newspaper

CAPE ARGUS, The (1997). 25 March, p.5.

Electronic source

DINOFFER, J. (2011). "Activities to build balance". *Prevent child obesity 101*. Hyperlink: [http: //*www*.preventchildobesity101.com/Activities/BalanceActivities.php]. Retrieved on 20 November 2012.

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For two authors: Johnson, A.G. & O'Kefee, L.M. (2003). Analysis of performance factors in provincial table tennis players. *Journal of Sport Performance*, 2(3), 12-31.

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Adams, L.L. & Neveling, I.A. (2004). Body fat characteristics of sumo wrestlers. In J.K. Manny & F.O. Boyd (Eds.), *Advances in Kinanthropometry (*pp. 21-29). Johannesburg, South Africa: The Publishers Company Ltd.

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- File for Figures and schemes must be provided during submission in a single zip archive and at a sufficiently high resolution (minimum 1000 pixels width/height, or a resolution of 300 dpi or higher). Common formats are accepted, however, TIFF, JPEG, EPS and PDF are preferred.
- *IJERPH* can publish multimedia files in articles or as supplementary materials. Please contact the editorial office for further information.
- All Figures, Schemes and Tables should be inserted into the main text close to their first citation and must be numbered following their number of appearance (Figure 1, Scheme I, Figure 2, Scheme II, Table 1, *etc.*).
- All Figures, Schemes and Tables should have a short explanatory title and caption.
- All table columns should have an explanatory heading. To facilitate the copy-editing of larger tables, smaller fonts may be used, but no less than 8 pt. in size. Authors should use the Table option of Microsoft Word to create tables.
- Authors are encouraged to prepare figures and schemes in colour (RGB at 8-bit per channel). There is no additional cost for publishing full colour graphics.

Supplementary Materials, Data Deposit and Software Source Code

Data Availability

In order to maintain the integrity, transparency and reproducibility of research records, authors must make their experimental and research data openly available either by depositing into data repositories or by publishing the data and files as supplementary information in this journal.

Computer Code and Software

For work where novel computer code was developed, authors should release the code either by depositing in a recognized, public repository or uploading as supplementary information to the publication. The name and version of all software used should be clearly indicated.

Supplementary Material

Additional data and files can be uploaded as "Supplementary Files" during the manuscript submission process. The supplementary files will also be available to the referees as part of the peer-review process. Any file format is acceptable, however we recommend that common, non-proprietary formats are used where possible.

Unpublished Data

Restrictions on data availability should be noted during submission and in the manuscript. "Data not shown" should be avoided: authors are encouraged to publish all observations related to the submitted manuscript as Supplementary Material. "Unpublished data" intended for publication in a manuscript that is either planned, "in preparation" or "submitted" but not yet accepted, should be cited in the text and a reference should be added in the References section. "Personal Communication" should also be cited in the text and reference added in the References section. (See also the MDPI reference list and citations style guide).

Remote Hosting and Large Data Sets

Data may be deposited with specialized service providers or institutional/subject repositories, preferably those that use the DataCite mechanism. Large data sets and files greater than 60 MB must be deposited in this way. For a list of other repositories specialized in scientific and experimental data, please consult databib.org or re3data.org. The data repository name, link to the data set (URL) and accession number, doi or handle number of the data set must be provided in the paper. The journal Data also accepts submissions of data set papers.

Deposition of Sequences and of Expression Data

New sequence information must be deposited to the appropriate database prior to submission of the manuscript. Accession numbers provided by the database should be included in the submitted manuscript. Manuscripts will not be published until the accession number is provided.

- *New nucleic acid sequences* must be deposited in one of the following databases: GenBank, EMBL, or DDBJ. Sequences should be submitted to only one database.
- *New high throughput sequencing (HTS) datasets* (RNA-seq, ChIP-Seq, degradome analysis) must be deposited either in the GEO database or in the NCBI's Sequence Read Archive.

- *New microarray data* must be deposited either in the GEO or the Array Express databases. The "Minimal Information about a Microarray Experiment" (MIAME) guidelines published by the Microarray Gene Expression Data Society must be followed.
- *New protein sequences* obtained by protein sequencing must be submitted to UniProt (submission tool SPIN).

All sequence names and the accession numbers provided by the databases should be provided in the Materials and Methods section of the article.

References in Supplementary Files

Citations and References in Supplementary files are permitted provided that they also appear in the reference list of the main text.

Research and Publication Ethics

Research Ethics

Research Involving Human Subjects

When reporting on research that involves human subjects, human material, human tissues, or human data, authors must declare that the investigations were carried out following the rules of the Declaration of Helsinki of 1975 (https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/), revised in 2008. According to point 23 of this declaration, an approval from an ethics committee should have been obtained before undertaking the research. At a minimum, a statement including the project identification code, date of approval and name of the ethics committee or institutional review board should be cited in the Methods Section of the article. Data relating to individual participants must be described in detail, but private information identifying participants need not be included unless the identifiable materials are of relevance to the research (for example, photographs of participants' faces that show a particular symptom). Editors reserve the right to reject any submission that does not meet these requirements.

Example of an ethical statement: "All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of XXX (Project identification code)."

A written informed consent for publication must be obtained from participating patients who can be identified (including by the patients themselves). Patients' initials or other personal identifiers must not appear in any images. For manuscripts that include any case details, personal information, and/or images of patients, authors must obtain signed informed consent from patients (or their relatives/guardians) before

submitting to an MDPI journal. Patient details must be anonymized as far as possible, e.g., do not mention specific age, ethnicity, or occupation where they are not relevant to the conclusions.

A template permission form is available to download. A blank version of the form used to obtain permission (without the patient names or signature) must be uploaded with your submission.

You may refer to our sample form and provide an appropriate form after consulting with your affiliated institution. Alternatively, you may provide a detailed justification of why informed consent is not necessary. For the purposes of publishing in MDPI journals, a consent, permission, or release form should include unlimited permission for publication in all formats (including print, electronic, and online), in sublicensed and reprinted versions (including translations and derived works), and in other works and products under open access license. To respect patients' and any other individual's privacy, please do not send signed forms. The journal reserves the right to ask authors to provide signed forms if necessary.

Ethical Guidelines for the Use of Animals in Research

The editors will require that the benefits potentially derived from any research causing harm to animals are significant in relation to any cost endured by animals, and that procedures followed are unlikely to cause offense to the majority of readers. Authors should particularly ensure that their research complies with the commonly-accepted '3Rs':

- Replacement of animals by alternatives wherever possible,
- Reduction in number of animals used, and
- Refinement of experimental conditions and procedures to minimize the harm to animals.

Any experimental work must also have been conducted in accordance with relevant national legislation on the use of animals for research. For further guidance authors should refer to the Code of Practice for the Housing and Care of Animals Used in Scientific Procedures [1].

Manuscripts containing original descriptions of research conducted in experimental animals must contain details of approval by a properly constituted research ethics committee. As a minimum, the project identification code, date of approval and name of the ethics committee or institutional review board should be cited in the Methods section.

IJERPH endorses the ARRIVE guidelines (www.nc3rs.org.uk/ARRIVE) for reporting experiments using live animals. Authors and reviewers can use the ARRIVE guidelines as a checklist, which can be found at www.nc3rs.org.uk/ARRIVEchecklist.

1. Home Office. Animals (Scientific Procedures) Act 1986. Code of Practice for the Housing and Care of Animals Used in Scientific Procedures. Available online: http://www.official-documents.gov.uk/document/hc8889/hc01/0107/0107.pdf.

Research Involving Cell Lines

Methods sections for submissions reporting on research with cell lines should state the origin of any cell lines. For established cell lines the provenance should be stated and references must also be given to either a published paper or to a commercial source. If previously unpublished *de novo* cell lines were used, including those gifted from another laboratory, details of institutional review board or ethics committee approval must be given, and confirmation of written informed consent must be provided if the line is of human origin.

An example of Ethical Statements:

The HCT116 cell line was obtained from XXXX. The $MLH1^{+}$ cell line was provided by XXXXX, Ltd. The DLD-1 cell line was obtained from Dr. XXXX. The DR-GFP and SA-GFP reporter plasmids were obtained from Dr. XXX and the Rad51K133A expression vector was obtained from Dr. XXXX.

Research Involving Plants

Experimental research on plants (either cultivated or wild) including collection of plant material, must comply with institutional, national, or international guidelines. We recommend that authors comply with the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

For each submitted manuscript supporting genetic information and origin must be provided. For research manuscripts involving rare and non-model plants (other than, e.g., *Arabidopsis thaliana*, *Nicotiana benthamiana, Oriza sativa*, or many other typical model plants), voucher specimens must be deposited in an accessible herbarium or museum. Vouchers may be requested for review by future investigators to verify the identity of the material used in the study (especially if taxonomic rearrangements occur in the future). They should include details of the populations sampled on the site of collection (GPS coordinates), date of collection, and document the part(s) used in the study where appropriate. For rare, threatened or endangered species this can be waived but it is necessary for the author to describe this in the cover letter.

Editors reserve the rights to reject any submission that does not meet these requirements.

An example of Ethical Statements:

Torenia fournieri plants were used in this study. White-flowered Crown White (CrW) and violet-flowered Crown Violet (CrV) cultivars selected from 'Crown Mix' (XXX Company, City, Country) were kindly provided by Dr. XXX (XXX Institute, City, Country).

Arabidopis mutant lines (SALKxxxx, SAILxxxx…) were kindly provided by Dr. XXX, institute, city, country).

Publication Ethics Statement

IJERPH is a member of the Committee on Publication Ethics (COPE). We fully adhere to its Code of Conduct and to its Best Practice Guidelines.

The editors of this journal enforce a rigorous peer-review process together with strict ethical policies and standards to ensure to add high quality scientific works to the field of scholarly publication. Unfortunately, cases of plagiarism, data falsification, image manipulation, inappropriate authorship credit, and the like, do arise. The editors of *IJERPH* take such publishing ethics issues very seriously and are trained to proceed in such cases with a zero tolerance policy.

Authors wishing to publish their papers in *IJERPH* must abide to the following:

- Any facts that might be perceived as a possible conflict of interest of the author(s) must be disclosed in the paper prior to submission.
- Authors should accurately present their research findings and include an objective discussion of the significance of their findings.
- Data and methods used in the research need to be presented in sufficient detail in the paper, so that other researchers can replicate the work.
- Raw data should preferably be publicly deposited by the authors before submission of their manuscript. Authors need to at least have the raw data readily available for presentation to the referees and the editors of the journal, if requested. Authors need to ensure appropriate measures are taken so that raw data is retained in full for a reasonable time after publication.
- Simultaneous submission of manuscripts to more than one journal is not tolerated.
- Republishing content that is not novel is not tolerated (for example, an English translation of a paper that is already published in another language will not be accepted).

- If errors and inaccuracies are found by the authors after publication of their paper, they need to be promptly communicated to the editors of this journal so that appropriate actions can be taken. Please refer to our policy regarding publication of publishing addenda and corrections.
- Your manuscript should not contain any information that has already been published. If you include already published figures or images, please obtain the necessary permission from the copyright holder to publish under the CC-BY license. For further information, see the Rights and Permissions page.
- Plagiarism, data fabrication and image manipulation are not tolerated.
    - **Plagiarism is not acceptable** in *IJERPH* submissions.

      Plagiarism includes copying text, ideas, images, or data from another source, even from your own publications, without giving any credit to the original source.

      Reuse of text that is copied from another source must be between quotes and the original source must be cited. If a study's design or the manuscript's structure or language has been inspired by previous works, these works must be explicitly cited.

      If plagiarism is detected during the peer review process, the manuscript may be rejected. If plagiarism is detected after publication, we may publish a correction or retract the paper.

    - **Image files must not be manipulated or adjusted in any way** that could lead to misinterpretation of the information provided by the original image.

      Irregular manipulation includes: 1) introduction, enhancement, moving, or removing features from the original image; 2) grouping of images that should obviously be presented separately (e.g., from different parts of the same gel, or from different gels); or 3) modifying the contrast, brightness or colour balance to obscure, eliminate or enhance some information.

      If irregular image manipulation is identified and confirmed during the peer review process, we may reject the manuscript. If irregular image manipulation is identified and confirmed after publication, we may correct or retract the paper.

Our in-house editors will investigate any allegations of publication misconduct and may contact the authors' institutions or funders if necessary. If evidence of misconduct is found, appropriate action will be taken to correct or retract the publication. Authors are expected to comply with the best ethical publication practices when publishing with MDPI.

Reviewer Suggestions

During the submission process, please suggest three potential reviewers with the appropriate expertise to review the manuscript. The editors will not necessarily approach these referees. Please provide detailed contact information (address, homepage, phone, e-mail address). The proposed referees should neither be current collaborators of the co-authors nor have published with any of the co-authors of the manuscript within the last five years. Proposed reviewers should be from different institutions to the authors. You may identify appropriate Editorial Board members of the journal as potential reviewers. You may suggest reviewers from among the authors that you frequently cite in your paper.

English Corrections

To facilitate proper peer reviewing of your manuscript, it is essential that it is submitted in grammatically correct English. Advice on some specific language points can be found here.

If you are not a native English speaker, we recommend that you have your manuscript professionally edited before submission or read by a native English-speaking colleague. This can be carried out by MDPI's English editing service. Professional editing will enable reviewers and future readers to more easily read and assess the content of submitted manuscripts. All accepted manuscripts undergo language editing, however **an additional fee will be charged** to authors if very extensive English corrections must be made by the Editorial Office: pricing is according to the service here.

Preprints and Conference Papers

IJERPH accepts articles that have previously been made available as preprints provided that they have not undergone peer review. A preprint is a draft version of a paper made available online before submission to a journal.

MDPI operates *Preprints*, a preprint server to which submitted papers can be uploaded directly after completing journal submission. Note that *Preprints* operates independently of the journal and posting a preprint does not affect the peer review process. Check the *Preprints* instructions for authors for further information.

Expanded and high quality conference papers can be considered as articles if they fulfil the following requirements: (1) the paper should be expanded to the size of a research article; (2) the conference paper should be cited and noted on the first page of the paper; (3) if the authors do not hold the copyright of the published conference paper, authors should seek the appropriate permission from the copyright holder; (4) authors are asked to disclose that it is conference paper in their cover letter and include a statement on what

has been changed compared to the original conference paper. *IJERPH* does not publish pilot studies or studies with inadequate statistical power.**Qualification for Authorship**

Each author is expected to have made substantial contributions to the conception or design of the work; acquisition, analysis, or interpretation of data; the creation of new software used in the work; and/or writing or substantively revising the manuscript. In addition, all authors must have approved the submitted version (and any substantially modified version that involves the author's contribution to the study); AND agrees to be personally accountable for the author's own contributions and for ensuring that questions related to the accuracy or integrity of any part of the work, even those in which the author was not personally involved, are appropriately investigated, resolved, and documented in the literature. Note that acquisition of funding, collection of data, or general supervision of the research group do not, by themselves, justify authorship.Those who contributed to the work but do not qualify for authorship should be listed in the acknowledgements.

More detailed guidance on authorship is given by the International Council of Medical Journal Editors (ICMJE). The journal also adheres to the standards of the Committee on Publication Ethics (COPE) that "all authors should agree to be listed and should approve the submitted and accepted versions of the publication. Any change to the author list should be approved by all authors including any who have been removed from the list. The corresponding author should act as a point of contact between the editor and the other authors and should keep co-authors informed and involve them in major decisions about the publication (e.g. answering reviewers' comments)." [1]. We reserve the right to request confirmation that all authors meet the authorship conditions.

1. Wager, E.; Kleinert, S. Responsible research publication: international standards for authors. A position statement developed at the 2nd World Conference on Research Integrity, Singapore, July 22-24, 2010. In Promoting Research Integrity in a Global Environment; Mayer, T., Steneck, N., eds.; Imperial College Press / World Scientific Publishing: Singapore; Chapter 50, pp. 309-16.

Editorial Procedures and Peer-Review

Initial Checks

All submitted manuscripts received by the Editorial Office will be checked by a professional in-house *Managing Editor* to determine whether they are properly prepared and whether they follow the ethical policies of the journal, including those for human and animal experimentation. Manuscripts that do not fit the journal's ethics policy or do not meet the standards of the journal will be rejected before peer-review. Manuscripts that are not properly prepared will be returned to the authors for revision and resubmission.

After these checks, the *Managing Editor* will consult the journals' *Editor-in-Chief*, *Associate Editor*, or *Guest Editor* (or an *Editorial Board member* in case of a conflict of interest) to determine whether the manuscript fits the scope of the journal and whether it is scientifically sound. No judgment on the significance or potential impact of the work will be made at this stage. Reject decisions at this stage will be verified by the *Editor-in-Chief*.

Peer-Review

Once a manuscript passes the initial checks, it will be assigned to at least two independent experts for peer-review. A single-blind review is applied, where authors' identities are known to reviewers. Peer review comments are confidential and will only be disclosed with the express agreement of the reviewer.

In the case of regular submissions, in-house assistant editors will invite experts, including recommendations by an academic editor. These experts may also include *Editorial Board members* and Guest Editors of the journal. In the case of a special issue, the *Guest Editor* will advise on the selection of reviewers.

Potential reviewers suggested by the authors may also be considered. Reviewers should not have published with any of the co-authors during the past five years and should not currently work or collaborate with any of the institutions of the co-authors of the submitted manuscript.

Editorial Decision and Revision

All the articles, reviews and communications published in MDPI journals go through the peer-review process and receive at least two reviews. The in-house editor will communicate the decision of the academic editor, which will be one of the following:

- *Accept after Minor Revisions*:
  The paper is in principle accepted after revision based on the reviewer's comments. Authors are given five days for minor revisions.
- *Reconsider after Major Revisions*:
  The acceptance of the manuscript would depend on the revisions. The author needs to provide a point by point response or provide a rebuttal if some of the reviewer's comments cannot be revised. Usually, only one round of major revisions is allowed. Authors will be asked to resubmit the revised paper within a suitable time frame, and the revised version will be returned to the reviewer for further comments.
- *Reject and Encourage Resubmission*:
  If additional experiments are needed to support the conclusions, the manuscript will be rejected

and the authors will be encouraged to re-submit the paper once further experiments have been conducted.

- *Reject*:
  The article has serious flaws, and/or makes no original significant contribution. No offer of resubmission to the journal is provided.

All reviewer comments should be responded to in a point-by-point fashion. Where the authors disagree with a reviewer, they must provide a clear response.

Author Appeals

Authors may appeal a rejection by sending an e-mail to the Editorial Office of the journal. The appeal must provide a detailed justification, including point-by-point responses to the reviewers' and/or Editor's comments. The *Managing Editor* of the journal will forward the manuscript and related information (including the identities of the referees) to the Editor-in-Chief, Associate Editor, or Editorial Board member. The academic Editor being consulted will be asked to give an advisory recommendation on the manuscript and may recommend acceptance, further peer-review, or uphold the original rejection decision. A reject decision at this stage is final and cannot be reversed.

In the case of a special issue, the *Managing Editor* of the journal will forward the manuscript and related information (including the identities of the referees) to the *Editor-in-Chief* who will be asked to give an advisory recommendation on the manuscript and may recommend acceptance, further peer-review, or uphold the original rejection decision. A reject decision at this stage will be final and cannot be reversed.

Production and Publication

Once accepted, the manuscript will undergo professional copy-editing, English editing, proofreading by the authors, final corrections, pagination, and, publication on the www.mdpi.com website.**Clinical Trials Registration**

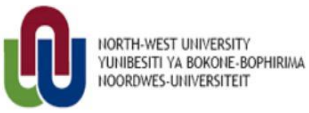
Registration

Authors are strongly encouraged to pre-register clinical trials with an international clinical trials register or and to cite a reference to the registration in the Methods section. Suitable databases include clinicaltrials.gov, the EU Clinical Trials Register and those listed by the World Health Organisation International Clinical Trials Registry Platform.

CONSORT Statement

IJERPH requires a completed CONSORT 2010 checklist and flow diagram as a condition of submission when reporting the results of a randomized trial. Templates for these can be found here or on the CONSORT website (http://www.consort-statement.org) which also describes several CONSORT checklist extensions for different designs and types of data beyond two group parallel trials. At minimum, your article should report the content addressed by each item of the checklist. Meeting these basic reporting requirements will greatly improve the value of your trial report and may enhance its chances for eventual publication.

APPENDIX B: LETTER TO THE DISTRICT OPERATIONAL DIRECTOR



School of Biokinetics, Recreation and Sport Science
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25 January 2010

The District Operational Director

Department of Education

North West Province

Potchefstroom

REQUEST TO CONDUCT RESEARCH WITHIN YOUR DISTRICT

Dear Sir,

We, the researchers from the School of Biokinetics, Recreation and Sport Science, hereby request permission to conduct research in the district under your authority.

To give the background of the study, research revealed that physical activity in adolescents is drastically declining. The decline in the level of physical activity of human populations has been observed, and such decline is being associated with increased mechanisation, reliance on technology and urbanisation, and the high rate of crime in South Africa and elsewhere in the world. Physical inactivity is thought to be one of the main risk factors for the development of obesity, diabetes, cardiovascular disease (CVD), osteoporosis and psychological constraints or risks of behavioural health.

Cross-sectional studies in South Africa which have investigated the relationship between physical activity and determinants of cardiovascular disease for children and adults are available. Findings from these studies have revealed that inactivity was significantly related to the determinants of cardiovascular disease. Little from the abovementioned studies could investigate physical activity and determinants of CVDs on a

longitudinal basis. It is therefore important to note that South Africa is a country of paradox where obesity in children coexists with malnutrition and many other ailments of health. It is, therefore, against this background that a longitudinal study investigating the development and tracking of physical activity and the determinants of cardiovascular diseases in South African adolescents is needed.

Adolescence is a time when independence is established, and dietary and activity patterns may be adopted that are followed for many years. Most of the physiological, psychological and social changes within people take place during this period of life. The period of adolescence can be looked upon as a time of more struggle and turmoil than childhood. Adolescents have long been regarded as a group of people who are searching for themselves to find some form of identity and meaning in their lives. Thus, it has great influence on adult fatness and chronic diseases of lifestyle as well as long-term outcome on quality of life. If youth health behaviours are tracked during adolescence, it would add support to the primary assumptions given for early interventions to prevent CVDs as well as delays in cognitive development. For this longitudinal study, tracking is defined as the stability of health behaviours over time, or the predictability of future values by early measurements. From the above given background, therefore, the aim of the study is to investigate over a five-year period (2010–2014) a follow-up longitudinal development of physical activity and determinants of health risk factors of health behaviour in 14-year-old adolescents attending schools in Potchefstroom area of the North West Province of South Africa.

The above matter background information refers:

1. Permission is requested to conduct research in selected schools in your district as follows:
    1.1 BA Seobi Sec. School
    1.2 Tlokwe High School
    1.3 Resolofetse High School
    1.4 Botokwa High School
    1.5 Potchefstroom High School for Boys
    1.6 Potchefstroom High School for Girls
    1.7 Hoer Volkskool Potchefstroom
    1.8 Potchefstroom Gimnasium School

2. The targeted groups are boys and girls aged 14 years, in essence, Grade 8 learners (NB: the proportion will be as follows: in mixed schools, 35 girls and 35 boys; and in black schools 30 boys and 30 girls will be required).
3. The targeted term is the first term of 2010 (to be continued during the same term in the subsequent years up until 2014).
4. Items to be assessed or measured are:
    4.1 Demographic information of the selected participants.
    4.2 Anthropomtric measurements (i.e. body height; weight; skinfolds thickness (triceps, sub-scapular and calf skinfolds); and waist and hip circumferences).

4.3 Maturation (Tanner questionnaire).

4.4 Blood pressure measurement (mercury sphygmomanometer).

4.5 Physical activity questionnaire.

4.6 ActiHeart (heart rate recorder with an integrated omnidirectional accelerometer which is clipped onto two ECG electrodes worn on the chest).

4.7 Health-related physical fitness (i.e. 20m shuttle run, standing broad jump, sit-and-reach, bent arm hang, sit-ups).

4.8 Social and self-efficacy questionnaire

4.9 Resting metabolic rate (determined by means of a mobile gas analyser).

4.10 Blood sampling (i.e. the participants will be requested to fast overnight for 10 hours). A fasting sample of 10 ml blood will be taken from each participant in order to obtain ample blood for the various analyses of the study).

4.11. Nutritional intake questionnaire.

4.12. Leisure and recreation constraint questionnaires.

5. The schedule of the project will be as follows (specific dates for selected schools will be finalised per arrangement with the principals concerned):

Month and week	Duration
April 2010, week 12–16	3 hours per child in a selected school
April 2010, week 19–23	3 hours per child in a selected school

Due to the fact that participants will be asked to fast 10 hours without eating breakfast in the morning, sandwiches will be provided upon completion of the measurements. The outcomes of this project will benefit the children and the schools with the information regarding the PA status and the determinants of health for future.

Hoping for a positive response.

Yours sincerely,

Thank you,

Prof M Andries Monyeki
(Principal Investigator, NWU-Potchefstroom)

Dr Hanlie Moss
Leader of Niche Area for Physical Activity, Sports and Recreation, NWU-Potchefstroom

APPENDIX C: INFORMED CONSENT FORM

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

School of Biokinetics, Recreation and Sport Science
Private Bag x6001,
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E-mail: andries.monyeki@nwu.ac.za

10 March 2010
http://www.nwu.ac.za

INFORMATION LETTER TO THE PARENTS AND CONSENT FORMS: *PAHLS STUDY*

Dear Parent or Guardian,

Your child is being invited to participate in a study entitled – Five-year Longitudinal Study of Physical Activity status and the determinants of health in adolescents attending high school in Potchefstroom areas of South Africa (*PAHLS Study, 2010–2014*).

My name is Professor Makama Andries Monyeki (from Potchefstroom Campus of the North-West University) principal investigator in the project, and together with the research team, would like to ask your permission to allow your child (or a child under your care) to participate in our study. To give the background of the study, research has revealed that physical activity in adolescents is drastically declining. The decline in the level of physical activity of human populations has been observed, and such decline is being associated with increased mechanisation, reliance on technology and urbanisation, and the high rate of crime in South Africa. Physical inactivity is thought to be one of the main risk factors for the development of obesity, diabetes, cardiovascular disease, osteoporosis and psychological constraints or risks of behavioural health. Therefore, the purpose of this study is to gather information about physical activity (i.e. by questionnaire & ActiHeart rate monitor) and health determinants (i.e. through measurements of anthropometry, maturation, blood pressure measurement, health-related physical fitness, social and self-efficacy questionnaire, resting metabolic rate, oxygen consumption (by the use of a portable gas analyser apparatus), blood sampling, leisure and recreation constraint questionnaires, nutritional intake questionnaire as questionnaire on risk factors of life) over a period of five years (2010– 2014).

Participation in this study is not part of the child's regular classroom work; it is an optional activity in which the learner can choose to participate. The study will assess and test the following variables: anthropometric

measurements, maturation, blood pressure measurement, health-related physical fitness, social and self-efficacy questionnaire, resting metabolic rate, oxygen consumption, blood sampling, leisure and recreation constraint questionnaires, and nutritional intake questionnaire as questionnaire on risk factors of life. Blood samples will be collected by a registered professional nurse who is obliged to health profession practices at all times.

The data of the study will be used for research purposes only. The measurements will not be shared with your child's classmates or teacher. All information collected in this study will be kept confidential. Your child's participation is important because the information that shall be gathered on him/her will help him/her with knowledge for personal development and life skills.

Your child's participation in the project is very important, but it is entirely your choice. If your child chooses to refuse to participate in any part of the study or withdraw from the study at any time, for any reason, this will not cause anyone to be upset or angry, and this will not result in any type of penalty.

There are no costs required from your child (or a child under your care) to participate in the study. Further, no payment will be granted to your child (or a child under your care) for participating in the study.

If you have any questions regarding this study, please feel free to call me at (018) 2991790 / e-mail: andries.monyeki@nwu.ac.za or the PHASrec Niche Area Leader Dr Hanlie Moss at (018) 2991821 / e-mail: hanlie.moss@nwu.ac.za. If you have any questions regarding your rights or your child's rights as participants in this study you can call Ms Hannekie Botha at (018) 299 4850 from Potchefstroom Campus of the North-West University Research Ethics Office.

Thank you in advance, for considering your child's participation in this study. Should you choose to allow your child to participate, please read and sign the attached consent form. Keep one consent form for your records and return the other copy. All received consent forms will be kept locked during the entire period of the study. In addition, your child is requested to bring along his/her birth clinic card. The card will be given back to the child immediately after collecting information on birth date and birth weight. A child who shall have returned a completed and signed consent form will participate in the study.

Sincerely,

Prof. Makama Andries Monyeki

Principal Investigator – PAHLS Study

CONSENT FORM

(Parent/Guardian Copy)

FIVE YEAR LONGITUDINAL STUDY OF PHYSICAL ACTIVITY STATUS AND THE DETERMINANTS OF HEALTH IN ADOLESCENTS ATTENDING HIGH SCHOOL IN POTCHEFSTROOM AREAS OF SOUTH AFRICA (*PAHLS STUDY, 2010–2014*).

I,....., father/mother/guardian of.....

agree to permit my child to provide the information on physical activity (i.e. by questionnaire and ActiHeart rate monitor) and health determinants (i.e. through measurements of anthropometry, maturation, blood pressure measurement, health-related physical fitness, social and self-efficacy questionnaire, resting metabolic rate, oxygen consumption (by the use of a portable gas analyser apparatus), blood sampling, leisure and recreation constraint questionnaires, nutritional intake questionnaire as questionnaire on risk factors of life), by the researchers at my child's school. I understand that the results of this five-year study of Longitudinal Study of Physical Activity status and the determinants of health in adolescents attending high school in Potchefstroom areas of South Africa (*PAHLS STUDY NWP*) will be used for research purposes and nothing else. I am aware that if I have any questions or concerns about the study I can contact the researcher at (018) 299 1790 or the PHASRec Niche Area Leader at (018) 299 1821. Any questions or concerns regarding my child's rights as a participant in this study can be addressed to Ms Hannekie Botha at (018) 299 4850 from Potchefstroom Campus of the North-West University Research Ethics Office. I understand that there will be no discomfort or foreseeable risks for my child to participate in the study. I understand that all information my child provides will remain strictly confidential. I have read and understood the information provided above and in the information letter. I have been provided with the opportunity to ask questions and my questions have been answered satisfactorily. I consent to have my child participate in the study described above, understanding that he/she may refuse to participate in any part of the study and can withdraw from the study at any time. I have kept one copy of this consent for my records and will return the second copy with the clinic birth card. I am aware that by giving consent my child can participate in the study. The return consent form will be kept locked during the entire period of the study.

Child’s Age:.....

Grade:.....

Teacher:.....

School Name:.....

Name of Child:.....

Name of Parent/Guardian:.....

(Signature of Child)

(Signature of Parent/Guardian)..... (Date) ……

APPENDIX D: ANTHROPOMETRIC DATA SHEET

PAHLS Project – Anthropometry Proforma

Subject number: ☐ Gender: Male ☐ Female ☐

Name: …… Sport: ……

Surname first names

Date of Birth:			
	Day	Month	Year

Test Date:			
	Day	Month	Year

Height ☐

	ID	*Site*	*Trial 1*	*Trial 2*	*Trial 3*	*Mean/ Median*
Basic	1	Body mass				
	2	Stature				
	3	Sitting height				
	4	Armspan				
Skinfolds	5a	Triceps : R				
(SF)	5b	Triceps : L				
(mm)	6a	Subscapular: R				
	6b	Subscapular: L				
	7a	Biceps: R				
	7b	Biceps: L				

	8a	Supraspinale : R				
	8b	Supraspinale : L				
	9	Abdominal : R				
	10a	Front thigh : R				
	10b	Front thigh : L				
	11a	Medial calf : R				
	11b	Medial calf : L				

Girths	12	Head				
GR	13a	Arm (relaxed) : R				
(cm)	13b	Arm (relaxed) : L				
	14a	Arm (flexed & tensed) : R				
	14b	Arm (flexed & tensed) : L				
	15	Waist (minimum)				
	16	Gluteal (hips)				
	17a	Thigh (mid) : R				
	17b	Thigh (mid) : L				
	18a	Calf (maximum) : R				
	18b	Calf (maximum) : L				

Breadths	19	Wrist				
BR	20	Ankle				
(cm)	21	Foot length				
	22	Humerus				
	23	Femur				

APPENDIX E: PHYSICAL ACTIVITY QUESTIONNAIRE

PHYSICAL ACTIVITY QUESTIONNAIRE (PAHLS-IPAQ)

A: GENERAL INFORMATION ABOUT YOU

School:	
Grade:	
School number:	
Name of the participant:	
Subject number:	
Address:	
Race:	

Date of Survey			**Grade**	**Sex (mark with an X)**		**Date of birth**			**Age**
dd	**mm**	**Yy**		**F**	**M**	**dd**	**mm**	**yy**	

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at school, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous/very hard** activities that you did in the **last 7 days**. **Vigorous/very hard** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

During the **last 7 days**, on how many days did you do **very hard** physical activities like heavy lifting, digging, aerobics or fast bicycling?

☐ **days per week**

No very hard physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **very hard** physical activities on one of those days?

☐ **hours per day**

☐ **minutes per day**

☐ **Don't know/not sure**

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

☐ **days per week**

No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

☐ **hours per day**

☐ **minutes per day**

☐ **Don't know/not sure**

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

☐ **hours per day**

☐ **minutes per day**

☐ **Don't know/not sure**

No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

☐ **hours per day**

☐ **minutes per day**

☐ **Don't know/not sure**

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **weekday**? (watching TV, video games/Internet, listening to music, reading)

☐ **hours per day**

☐ **minutes per day**

☐ **Don't know/not sure**

This is the end of the questionnaire, thank you for participating.

APPENDIX F: LANGUAGE EDITOR'S CRTIFICATE

Lesley Suzanne Wyldbore

PO Box 130211 Bryanston 2021
e-mail: lesleywyldbore@gmail.com

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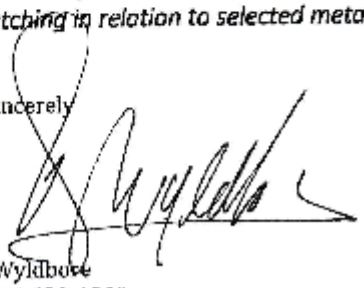
18 June 2018

To Whom it May Concern

I, Lesley Wyldbore, do herewith confirm that I have conducted an English language and grammar edit on the PhD dissertation by Vincent Masocha entitled:

Two-year longitudinal changes in body composition, physical activity and TV watching in relation to selected metabolic risk factors: the PAHL study

Yours sincerely



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