The relationship between physical activity and markers of the metabolic syndrome in adolescents: the PAHL-study

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Dissertation submitted in fulfillment of the requirements for the degree *Master of Science* in Biokinetics at the Potchefstroom Campus of the North-West University

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DECLARATION

The co-authors of the articles included in this dissertation, Prof SJ Moss (Supervisor) and Prof MA Monyeki (co-supervisor) hereby give permission to the candidate, Ms. Caroline Madise to include the 2 articles as part of her masters degree dissertation. The contribution (advisory and supportive) of these co-authors was kept within reasonable limits, thereby enabling the candidate to submit this dissertation for examination purposes. This dissertation, therefore serves as fulfilment of the requirements for the MSc. degree in Biokinetics within the research focus area for Physical Activity, Sport and Recreation in the Faculty of Health Sciences at the North-West University, Potchefstroom Campus.

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SUMMARY

The relationship between physical activity and markers of the metabolic syndrome in adolescents: the PAHL-study

Low levels of physical activity (PA) are associated with a dramatic rise in obesity. The increase in prevalence of overweight and obesity is in parallel with an increase in metabolic syndrome (MetS) prevalence. Numerous studies have documented decreasing levels of PA together with an increase in overweight and obesity in South African adolescents. Few studies which could be found indicated that the prevalence of MetS in adolescents is high. Information on the prevalence of MetS and how it relates to PA levels in South African adolescents is scanty. It was therefore appropriate to use data from Physical Activity and Health Longitudinal Study (PAHLS) with the overarching aim of describing the development of PA and the determinants of health risk factors in 14-18 year-old adolescents longitudinally to answer the following questions. Firstly, what is the prevalence of MetS in adolescents residing in the Tlokwe Municipality of the North West Province? Secondly, what is the relationship between PA levels and the MetS markers of adolescents in the Tlokwe Municipality of the North West Province?

Adolescents from six high schools from both high and low socioeconomic areas were recruited to take part in the study. A total of 215 adolescents aged 15 years gave consent for blood sampling and of those, a 188 completed the PA questionnaire using the short form of the International Physical Activity Questionnaire (IPAQ-S). The following variables; body mass, stature, waist and hip circumference, glucose, high density lipoprotein, triglycerides and blood pressure were determined according to standard procedures. PA measures were categorised as follows; vigorous PA, walk PA and total PA as metabolic equivalents minutes per week (MET min/week). Daily moderate to vigorous physical activity (MVPA) was also computed to classify adolescents as either meeting the PA guidelines or not meeting the guidelines of ≥60 min/day of MVPA.

Data was analysed with SPSS IBM software version 22. Descriptive statistics were computed to give participants characteristics in terms of means and standard deviations as well as median and interquartile range for PA parameters. Spearman (rho) correlation was performed to determine the relationship between PA levels and MetS markers. Odds ratios were calculated to establish the level of risks for being classified as having the MetS in terms of not meeting recommended 60 min/day MVPA versus persons meeting the recommended MVPA guidelines.

The results indicate that only 25% of the adolescent included in the study met the recommended PA guidelines. The findings also indicate that the prevalence of MetS is 2.3% and 5.6% with IDF and NCEP/ATP III criteria respectively. Prevalence of MetS is significantly higher in the overweight compared to the normal weight ($p<0.05$) participants. The results further revealed that 7.9% and 22.9% (IDF and NCEP criteria respectively) of the adolescents presented with two or more of the risk factors of MetS. Vigorous PA was reported to be inversely associated with DBP ($r=-0.14$; $p=0.05$). No significant relationship was noted between PA measures and the other markers of MetS. The odds of being diagnosed with MetS when applying the NCEP/ATP III criteria when not meeting recommended PA guidelines is 2.4 times higher than when meeting the PA guidelines. No clear relationship was noted when MetS was diagnosed with the IDF criteria. These findings were however not significant with either diagnostic criteria.

Adolescents aged 15 years in Tlokwe Municipality of the North West Province are not adequately active and this inactivity possibly contributes to the overweight observed and associated high prevalence of MetS. An increase in PA might reduce the risk of MetS via the mechanism that reduces blood pressure.

[Keywords: Metabolic syndrome, prevalence, physical activity, obesity, adolescents]

OPSOMMING

Die verhouding tussen fisieke aktiwiteit en merkers van die metaboliese sindroom in adolessente: die PAHL-studie

Lae vlakke van fisieke aktiwiteit (FA) word geassosieer met 'n dramatiese toename in vetsug. Die toename in die voorkoms van oorgewig en vetsug is in ooreenstemming met 'n toename in die voorkoms van die metaboliese sindroom (MetS). Verskeie studies is al gedokumenteer oor die dalende vlakke van FA tesame met 'n toename in oorgewig en vetsug in Suid-Afrikaanse tieners. Min studies wat die voorkoms van MetS in adolessente aandui kon gevind word. Inligting oor die voorkoms van MetS en hoe dit verband hou met FA vlakke in Suid-Afrikaanse tieners is skaars. Dit was dus gepas om die data van die Physical Activity and Health Longitudinal Study (PAHLS) wat geloots is, met die hoofdoel om die ontwikkeling van FA en die bepalende faktore van gesondheidsrisiko in 14-18 jarige tieners te beskryf, te gebruik om die volgende vrae te beantwoord. Eerstens, wat is die voorkoms van MetS in adolessente wat in die Tlokwe Munisipaliteit van die Noordwesprovinsie woonagtig is? In die tweede plek, wat is die verhouding tussen FA vlakke en die MetS merkers van adolessente in die Tlokwe Munisipaliteit van die Noordwesprovinsie?

Adolessente uit ses hoërskole van beide hoë en lae sosio-ekonomiese gebiede is gewerf om aan die studie deel te neem. ʼn Totaal van 215 adolessente met die ouderdom van 15 jaar het toestemming verleen vir die neem van ʼn bloedmonster en 188 het die FA vraelys voltooi met behulp van ʼn verkorte vorm van die International Physical Activity Questionnaire (IPAQ-S). Die volgende veranderlikes is bepaal volgens standaard prosedures: liggaamsmassa, lengte, middellyf en heup omtrek, glukose vlakke, hoë digtheid lipoproteïen, trigliseriede konsentrasie en bloeddruk. FA maatreëls is gekategoriseer soos volg: intense FA, stap vir FA en totale FA as metaboliese ekwivalente minute per week (MET min/week). Daaglikse matige tot hoë intensiteit fisiese aktiwiteit is ook bereken om adolessente te klassifiseer volgens dié wat óf voldoen aan die FA riglyne of nie voldoen aan die riglyne van ≥60 min/dag matig tot hoë intensiteit fisiese aktiwiteit.

Data is geanaliseer met behulp van SPSS IBM sagteware, weergawe 22. Beskrywende statistiek is bereken om eienskappe aan deelnemers toe te ken in terme van gemiddeldes en standaardafwykings asook mediaan en interkwartiel variasiewydte vir FA parameters. Spearman (rho) korrelasie is uitgevoer om die verhouding tussen FA vlakke en MetS merkers te bepaal.

Die kans geklassifiseer te word met MetS, indien nie voldoen word aan die 60 min/dag MSFA teenoor die aanbevole matig tot hoë intensiteit fisiese aktiwiteit riglyne nie, is bereken.

Die resultate dui daarop dat slegs 25% van die adolessente wat in die studie ingesluit is, voldoen het aan die aanbevole FA riglyne. Die bevindinge dui ook aan dat die voorkoms van MetS 2,3% en 5,6% met IDF en NCEP/ATP III kriteria onderskeidelik is. Die voorkoms van MetS is aansienlik hoër in die oorgewig deelnemers in vergelyking met deelnemers met ŉ normale massas ($p < 0.05$). Die resultate het verder aan die lig gebring dat 7,9% en 22,9% (IDF en NCEP kriteria onderskeidelik) van die adolessente twee of meer van die risikofaktore van MetS getoon het. Dit is aangemeld dat hoë FA intensiteit ŉ omgekeerde verband het met DBP ($r = -0,14$; $p = 0.05$). Geen beduidende verband is opgemerk tussen FA vlakke en die oorblywende merkers van MetS nie. Die kans om met MetS gediagnoseer te word wanneer die NCEP/ATP III kriteria toegepas word wanneer nie aan FA riglyne voldoen word nie, is 2,4 keer hoër as wanneer wel voldoen word aan FA riglyne. Geen verwantskap is gevind toe IDF kriteria gebruik om MetS gediagnoseer nie.

Adolessente van 15 jarige ouderdom in die Tlokwe Munisipaliteit van die Noordwes Provinsie is nie voldoende aktief nie en hierdie onaktiwiteit kan moontlik bydra tot oorgewig en die gepaardgaande hoë voorkoms van MetS. 'n Toename in FA kan die risiko van MetS verminder deur middel van ŉ verlaging in bloeddruk verlaag.

[Sleutelwoorde: Metaboliese sindroom, voorkoms, fisieke aktiwiteit, vetsug, adolessente]

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LIST OF ABBREVIATIONS

AEE	Activity energy expenditure
AHA	American Heart Association criteria
BMI	Body mass index
CVD	Cardiovascular disease
CVDs	Cardiovascular diseases
DBP	Diastolic blood pressure
Gluc	Glucose
HC	Hip circumference
HDL-C	High density lipoprotein-Cholesterol
IDF	International diabetes federation
JEMDSA	Journal of Endocrinology, Metabolism and Diabetes of South Africa
JPAH	Journal of physical activity and health
IPAQ	International physical activity questionnaire
ISAK	International Society for the Advancement of Kinanthropometry
IR	Insulin resistance
METs	Metabolic equivalents
MetS	Metabolic syndrome
NCEP/ATP III	National Cholesterol Education Programme/Adult Trial Panel III
MRC	Medical Research Council of South Africa
MVPA	Moderate-to-vigorous physical activity

NRF	National Research Foundation
PAHLS	Physical activity and health longitudinal study
PAHL	Physical activity and health longitudinal
PA	Physical activity
PAL	Physical activity level
Trig	Triglycerides
SBP	Systolic blood pressure
SES	Social-economic status
SD	Standard deviation
WC	Waist circumference
WHO	World Health Organization
NWU	North West University

CHAPTER 1

INTRODUCTION

1.1 Introduction

Although the literature on the prevalence of metabolic syndrome (MetS) in adolescents is sparse compared to adults, it remains evident that percentages are high, and can be carried into adulthood without prompt intervention (Steinberger *et al.*, 2009:638). MetS has detrimental health effects, it increases the risk of cardiovascular diseases and diabetes mellitus (Isomaa *et al.*, 2001:687). The odds of acquiring MetS increase with low physical activity (PA) levels and the presence of obesity. (Chu & Moy, 2014:199; Pan & Pratt, 2008:284). Chapter 1 present the problem statement for the relationship between PA levels and markers of the MetS. Presented also in the chapter are the research questions, objectives and hypothesis on which the study is based.

1.2 Problem statement

Metabolic syndrome is associated with an increased risk of cardiovascular morbidity and mortality in adults (Isomaa *et al.*, 2001:687). Steinberger *et al.* (2009:638) indicated that the risk factors associated with MetS manifest early during childhood. 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). Lower levels of PA and higher levels of sedentary behaviour, especially watching TV, videos and resting, are associated with an increased likelihood of developing MetS in adults and children (Chu & Moy, 2014:199; Väistö *et al*., 2014:7). The components used in the diagnosis of MetS include increased waist circumference (WC), 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).

There are different criteria for the diagnosis of MetS, and the cut-off points thereof are slightly different (Corte *et al*., 2015:49). Criteria used include: International Diabetes Federation (IDF criteria), National Cholesterol Education Programme/Adult Trial Panel III (NCEP/ATP III) criteria, and World Health Organization (WHO) criteria (Corte *et al*., 2015:49) The IDF criteria for any person between the ages of 10–16 years stipulates the presence of central obesity and abnormalities in any two of the following variables: Triglycerides, HDL-C, glucose or blood pressure (Zimmet *et al*., 2007:304). The NCEP/ATP III criteria considered for 12–19 year-olds are the presence of abnormalities in any three or more of the following components required: WC, triglycerides, HDL-C, fasting glucose, and blood pressure (Corte *et al*., 2015:49). The WHO criteria are defined by the presence of diabetes mellitus, insulin resistance, or impaired fasting glucose and abnormalities in any two of the following variables: Blood pressure, triglycerides, HDL-C, central obesity and micro-albuminuria (WHO, 1998:32–33). Although there is no agreement about the criteria used for the definition of MetS in adolescents, IDF seems appropriate for this group: it divides children into different age groups and there are specific cut-off points for each age group, except below the age of six (Mancini, 2009:4; Silveira *et al*., 2013:5). Both the IDF and NCEP/ATP III are commonly used for diagnosis of MetS in adolescents (Silveira *et al.*, 2013: 3), and in adolescents, percentiles are used as cut-off points in most of the components rather than the absolute values that are used in adult populations (Jessup & Harrell, 2005:26).

Abnormalities in the components of MetS are noted in obese and underactive American adolescents (McMurray *et al.*, 2008:5; Pan & Pratt, 2008:284). It has been suggested that intervention early in life that is aimed at reducing obesity, such as PA intervention, can lower the risk of developing MetS (Steinberger *et al*., 2009:638; Zeelie *et al*., 2010a:293). Although insulin resistance increases with puberty (Jessup & Harrell, 2005:26), regular PA has been shown to improve insulin sensitivity (Platat *et al*., 2006:2084) and as in adults, insulin resistance in children is strongly associated with specific adverse metabolic factors (Weiss *et al*., 2004:2370). Higher levels of adiposity are associated with low levels of PA and high sedentary behaviour (Ojiambo *et al.,* 2012:122). There are notable improvements in blood pressure measurements, lipid profile and insulin sensitivity with PA intervention (Zeelie *et al*., 2010a:294).

Physical activity is defined as any bodily movement produced by skeletal muscles that result in energy expenditure (Caspersen *et al*., 1985:126). It is recommended that school age youth participate in 60 minutes or more of moderate-to-vigorous PA daily for a minimum of three times a week. This proposed recommendation can be seen as a health promotion and disease-prevention strategy (Martinez-Gomez *et al*., 2010:209; Strong *et al*., 2005:736; WHO, 2010:20). PA is shown to decrease from childhood to adolescent stage (McVeigh & Meiring, 2014:375; Riddoch *et al*., 2004:90); the levels appearing to decline by half by the time the adolescents reach high school (McVeigh & Meiring, 2014:375).

Studies in South Africa have reported that adolescents spend more time in sedentary rather than active behaviour (Craig *et al*., 2013:83; McVeigh & Meiring, 2014:377; Micklesfield *et al*., 2014:8). Similar results have also been reported in other countries in Africa (Peltzer, 2010:275; Shokrvash *et al*., 2013:5), as well as in other continents such as Europe (Belton *et al.,* 2014:12) and America (Pan & Pratt, 2008:284). A larger percentage of adolescents do not meet the recommended daily moderate-to-vigorous PA level of 60 minutes per day (Belton *et al.,* 2014:12; Craig *et al*., 2013:83; Micklesfield *et al*., 2014:8; Wushe *et al*., 2014:4). Marked differences in daily PA volumes and intensities can be observed between adolescents from rural and urban areas, with adolescents from urban areas found to be more sedentary and having lower levels of PA (Muthuri *et al*., 2014:3352; Ojiambo *et al.*, 2012:122; Peltzer, 2010:275). However, one study conducted in rural Kwa-Zulu Natal reported that although adolescents had high PA levels they were at low intensity and thus did not meet the recommended level (Craig *et al.*, 2013:83).

Socioeconomic status (SES) also plays a role in the levels of PA in adolescents, as lower levels of SES are associated with less sedentary time and lower moderate-to-vigorous PA (Micklesfield *et al.,* 2014:7). Higher SES, on the other hand, is associated with more sedentary behaviour but more time participating in moderate-to-vigorous PA at schools and clubs (Micklesfield *et al.,* 2014:7; Muthuri *et al*., 2014:3352). A study conducted on South African school children and adolescents living in an urban area and attending a semi-private school found that black children spent most of their time in sedentary behaviour and less time being physically active in comparison to whites and Indians (McVeigh & Meiring, 2014:376). Females are reported to show lower levels of PA compared to males (McVeigh & Meiring, 2014:375; Muthuri *et al*., 2014:3343; Shokrvash *et al.,* 2013:7). The most common reasons seen as barriers to doing PA by adolescents include too many responsibilities at school, spending more time studying (as most parents view this to be more important than exercise), and lack of motivation and interest (Kalac *et al*., 2014:55).

Lower levels of PA are associated with a dramatic rise in obesity, which is found to be associated with an increase in the prevalence of MetS in developing countries (Kelishadi, 2007:69; Misra & Khurana, 2008:12–13). In adults, a combination of a reduction in energy intake and an increase in energy expenditure through any form of structured exercise or PA has been shown to reduce the probability of becoming overweight or obese, and hence the prevention of MetS (Chu & Moy, 2014:199). The prevalence of MetS was reported to be 31.9% in Asian adults (Chu & Moy, 2014:199) and 23.3% in South African adults; it has also been reported as more prevalent in women than in men (Motala *et al*., 2011:1033), and the odds of MetS increase with low PA (Chu & Moy, 2014:199).

Even though there is not enough data on MetS in children compared to adults, it is clear that the risk factors that predispose MetS begin in childhood (Steinberger *et al.,* 2009:638). MetS is common in children and adolescents and it is more prevalent in those who are obese (Cruz & Goran, 2004:60-61; Tailor *et al*., 2010:210; Weiss *et al.*, 2004:2371). A study of adolescents in the United States found that the prevalence of MetS in the overall population was 3.5% and 14.5% in overweight adolescents (Pan & Pratt, 2008:283). The prevalence was lower in adolescents who had higher PA levels and this suggests the beneficial effect of high PA in reducing MetS (Pan & Pratt, 2008:283). In the youth from Calanga, Mozambique, the prevalence of MetS was reported to be low at <2%, and the reason for this was the higher level of PA in these adolescents (Dos Santos *et al.,* 2013:19). The prevalence of MetS in South African adolescents from the Western Cape was reported to be 6.5% with NCEP/ATP and 1.9% with IDF. The percentage difference between the two criteria was statistically significant: NCEP/ATP III shows a much higher prevalence than the IDF (Matsha *et al*., 2009:363). A prevalence of 3.7% with NCEP/ATP III has also been found in another similar study (Rensburg *et al*., 2012:3). The rates are higher among whites, followed by blacks and then coloureds, and across all races, males and the overweight/obese have the highest prevalence of MetS (Matsha *et al*., 2009:363).

Low levels of PA in the Tlokwe Municipality have been reported, as over 60% of adolescents do not meet the recommended 60 minutes per day of moderate-to-vigorous PA (Wushe *et al*., 2014:4), making them susceptible to the risk of obesity, hypertension and diabetes. A high prevalence of overweight and obesity has also been reported in South African children and adolescents (Rossouw *et al*., 2012:913; Monyeki *et al*., 2012:377). Although similar studies that determine the prevalence of MetS and how its markers relate to PA have been conducted, sparse information exists in the literature regarding the relationship between PA and markers of the MetS (Pan & Pratt, 2008:285; Zeelie *et al*., 2010a:294), especially in South African adolescents. The current study seeks to answer the following questions:

- Firstly, what is the prevalence of MetS in adolescents residing in the Tlokwe Municipality of the North West Province?
- Secondly, what is the relationship between PA levels and the MetS markers of adolescents in the Tlokwe Municipality of the North West Province?

The results of the current study will add knowledge to the existing literature regarding the prevalence of MetS and its association with PA among adolescent in the Tlokwe Municipality. Additionally, the findings of this study will provide professionals working with adolescents with scientifically based valuable information which may help them in the design of strategic intervention programmes.

1.3 Objectives

The objectives of this study were to determine:

- The prevalence of MetS according to the IDF and NCEP/ATP III criteria in adolescents residing in the Tlokwe Municipality of the North West Province.
- The relationship between PA levels and the MetS markers of adolescents in the Tlokwe Municipality of the North West Province.

1.4 Hypotheses

This study is based on the following hypotheses:

- A higher prevalence of MetS will be present according to the IDF compared to the NCEP/ATP II criteria in adolescents residing in the Tlokwe Municipality of the North West Province.
- There will be a significant inverse relationship between PA levels and the MetS markers of adolescents residing in the Tlokwe Municipality of the North West Province.

1.5 Structure of the dissertation

The PAHL-study lend itself to researching the proposed objectives. Participation in the PAHL-study was data collection, capturing, analyses and drafting of the manuscripts. The structure of the dissertation would be in the form of the article model and consist of five chapters.

Chapter 1: This chapter is the introductory chapter, which comprises the problem statement, two objectives and the corresponding hypotheses to be tested in the study. The reference list is written according to Harvard referencing style which have been adapted by the North-West University and is presented at the end of the chapter.

Chapter 2: This is a literature review chapter which discusses in detail the relationship between PA and markers of the MetS in adolescents. The reference list is written according to Harvard reference guidelines which have been adapted by the North-West University and is presented at the end of the chapter.

Chapter 3: Article 1: Prevalence of the MetS in South African adolescents according to IDF and NCP/ATP III criteria: the PAHL-study. This article is written according to the author's guidelines of the *Journal of Endocrinology, Metabolism and Diabetes of South Africa* where this article is submitted for publication. The author guidelines are attached as an appendix (Guidelines for authors) at the end of the dissertation.

Chapter 4: Article 2: Relationship between physical activity levels and metabolic syndrome markers of adolescents from the North West Province: the PAHL-study. The article is written according to the authors guidelines for the *Journal of physical activity and health.* The article will be submitted for publication to this journal and the author guidelines are attached as an appendix (Guidelines for authors) at the end of the dissertation.

Chapter 5: This chapter consists of a summary, conclusions, limitations and recommendations based on the overall findings of the two above-mentioned objectives. The reference list is written according to Harvard reference style which has been adapted by the North-West University and is presented at the end of the chapter.

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CHAPTER 2

LITERATURE REVIEW: PHYSICAL ACTIVITY AND METABOLIC SYNDROME IN ADOLESCENTS

2.1 Introduction

Between the years 2007 and 2030 premature death due to cardiovascular diseases (CVDs) in adults in South Africa is set to rise by 41%. This will have a negative impact on the country's economy (Heart Disease Fact Sheet). Increased risk of cardiovascular morbidity and mortality in adults is perpetuated by the presence of metabolic syndrome (MetS) (Isomaa *et al.,* 2001:687). Clusters associated with MetS start in childhood (Steinberger *et al*., 2009:638). Metabolic syndrome is defined as 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 to define MetS include increased waist circumference (WC), 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). According to the literature, there are different criteria for defining MetS with slightly different cut-off points for each of the risk factors presented (Corte *et al*., 2015:49) making it difficult to compare the prevalence of MetS consistently.

The prevalence of MetS in children and adolescents is rising dramatically (Friend *et al*. 2013). Overweight and obesity due to bad diet, low physical activity (PA) and high sedentary behaviour are the most important factors contributing to the high percentages found earlier in life (Friend *et al*., 2013:74; Jessup & Harrell. 2005:30; Weiss *et al*., 2004:135). The risk factors of MetS in childhood track well into adulthood (Morrison *et al*., 2008:204). Promotion of PA at an early age may prevent obesity and the development of insulin resistance (IR), lowering the risk of developing MetS, since both factors are strongly associated with MetS (Platat *et al*., 2006:2084; Steinberger *et al*., 2009:638; Weiss *et al*., 2004:2370; Zeelie *et al*., 2010a:293). High PA levels are associated with health benefits. However, the reality is that PA levels are decreasing significantly, leading to unfavourable health changes and premature death (Warburton *et al*., 2006:801). Lower levels of PA and higher levels of sedentary behaviour (especially watching TV, videos and resting) increase the odds of being overweight or obese (Martinez-Gomez *et al*., 2010:201).

2.2 Physical activity

2.2.1 Trends in physical activity levels and sedentary behaviour

Physical activity is defined as bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen *et al*., 1985:126). Physical activity can be segmented into different categories depending on when and why it is performed; it can be divided into sleeping activity, and work, commuting and leisure-time PA (Caspersen *et al*., 1985:127). Domains of PA that contribute significantly to the overall level of daily or weekly PA vary according to age group. In childhood, activities are more anaerobic (Strong *et al*., 2005:736). Children play games that assist them in learning both basic and more specialised motor skills. As children progress into puberty they focus more on a variety of individual and group activities as well as a number of organised sports (Strong *et al*., 2005:736). In adulthood, PA domains include household chores, and occupational, leisure time, and transportation PA as well as sports or planned exercise (WHO, 2010:26).

Numerous studies recommend that children of school age should participate in 60 minutes or more of moderate-to-vigorous physical activity (MVPA) daily (Martinez-Gomez *et al*., 2010:209; Strong *et al*., 2005:736; WHO, 2010:20). The recommended 60 minutes per day (min/day) of physical activity need not be achieved all in one session or time frame. Physical activity can be accumulated with different activities such as sports participation, school physical education programmes, and extramural programmes (Strong *et al*., 2005:737). Not all children and adolescents achieve the recommended PA guidelines though. Physical activity trend analysis in ten Eastern Mediterranean countries showed that schoolgoing adolescents are not sufficiently physically active. Only 19% met the recommended PA level (Al Subhi *et al.*, 2015:259). Self-reporting data of PA from adolescents between the ages of 12–14 years from a rural Irish town showed that only 33% of the adolescents met the recommended 60 min/day of MVPA for all seven days of the week (Belton *et al*., 2014:10).

African countries are not outside of this high prevalence of physical inactivity; approximately 50% of Kenyan and 37% of Nigerian adolescents are adequately active (Adeniyi *et al*., 2016:233; Wachira *et al.*, 2014:70), while below 60% of Mozambique and Zimbabwean adolescents achieve the recommended PA guidelines (Manyanga *et al.*, 2016:338; Prista *et al.*, 2016:215). According to the 2014 Healthy Active Kids South Africa Report Card less than 50% of children and adolescents were adequately active, however, according to the 2016 report card at least 50% are achieving the set guidelines for PA (Draper *et al*., 2014:100; Uys *et al.*, 2016: 267). Although there has been some improvement in the overall PA levels of South African children and adolescents, levels are still too low. This situation should be of concern to all South Africans given the risk factors associated with physical inactivity, and thus the time has come to engage parents and communities in advocacy and social mobilisation (Draper *et al.,* 2014:103).

Marked differences in daily PA volumes and intensities have been observed between adolescents from rural and urban areas. Adolescents from urban areas achieve lower PA volumes compared to those from rural areas (Ojiambo *et al*., 2012:122; Peltzer, 2010:275; Muthuri *et al*., 2014:3352). This, however, does not imply that adolescents from rural areas achieve PA guidelines more than those from urban areas. A study on rural Kwa-Zulu Natal children and adolescents reported high volumes of PA at relatively low intensities with only a minority achieving the recommended level of PA (Craig *et al*., 2014:83). Adolescents from a semi-urban area in Gauteng spent a considerable amount of time walking and that was the main contributor to total PA. As walking was carried out at relatively low intensity, the majority did not achieve the set PA guidelines (van den Berg & Grobler, 2014:911).

Physical activity levels decline with an increase in school grade and age (Brodersen *et al*., 2007:141). A study on PA levels in adolescents in the Czech Republic over a 12-year period indicated that at baseline 32.2% boys and 23.2 % girls met the PA guidelines. At the end of the study, the numbers had declined significantly with only 25.6% of boys and 19.2% of girls meeting the recommended guidelines of PA (Sigmund *et al*., 2015:11854). Similarly to adolescents in other countries, PA levels decline with an increase in age and school grade in South Africa (McVeigh & Meiring, 2014:375; Riddoch *et al*., 2004:90). Older adolescents are more prone to low activity participation compared to the younger adolescents (Draper *et al*., 2014:100).

Apart from age, another determinant of PA is gender. Females are reported to show lower levels of PA compared to their male counterparts (McVeigh & Meiring, 2014:375; Muthuri *et al*., 2014:3343; Shokrvash *et al*., 2013:7). In Kenyan adolescents, more boys (17.6%) than girls (8.3%) met the recommended PA guidelines (Muthuri *et al*., 2014:11). The Report Card for South African Kids of 2014 indicated that girls (39%) are prone to insufficient activity compared to boys (16%) (Draper *et al*., 2014:100). In adolescents from Mpumalanga, boys spent significantly more time in MVPA compared to girls (median of 60 in girls *vs* 360 in boys) (Micklesfield *et al*., 2014:8). Similarly, a study in children and adolescents from Gauteng and Kwa-Zulu Natal reported that more boys than girls achieve high PA levels (Craig *et al*., 2014:82; McVeigh & Meiring 2014:373). Not all studies report these phenomena; Wushe and colleagues

(2014:5) reported that adolescent girls from the Tlokwe Municipality spend more time in MVPA than their male counterparts.

Since it is evident that children are not adequately active, it is necessary to understand what they are spending their leisure time on if not being physically active. Decrease in PA levels is in parallel with increases in sedentary behaviour (Brodersen *et al*., 2007:141). Sedentary behaviour is defined as being engaged in activities that involve energy expenditure of less than 1.5 metabolic equivalents (METs) (Pate *et al*., 2008:174). This includes activities such as lying in bed, watching television and playing computer games. A review article on leisure time PA and sedentary behaviour in adolescents in African countries found that 28.7% of the participants spend more than three hours sitting, and 11.2 % spend more than five hours on a usual day in sedentary behaviour (Peltzer, 2010:275). Overall, 29% of adolescents from ten Eastern Mediterranean countries were found to be sedentary (Al Subhi *et al*., 2015: 260). South African adolescents are no different, spending on average three hours watching TV on weekdays with the time increasing to 3.5 hours on weekends (Draper *et al*., 2014:101). A contributing factor to sedentary time is socioeconomic status (SES) with adolescents from high-income countries more sedentary than those from low-middle income countries (Al Subhi *et al*., 2015: 260). In adolescents, lower levels of SES are associated with less sedentary time and lower MVPA (Micklesfield *et al*., 2014:7). Higher SES, on the other hand, is associated with more sedentary behaviour but more time participating in MVPA (Micklesfield *et al*., 2014:7; Muthuri *et al*., 2014:3352).

Similarly to adolescents, the majority of adults are not achieving recommended PA guidelines and the decline in PA increases as they grow older (Assah *et al*., 2015:701; Hallal *et al*., 2014:1527). Males achieve PA guidelines more than their female counterparts (Hallal *et al*., 2014:1527). Urbanisation also plays a role in the levels of PA in adults as in children, with those from rural areas more physically active than those in urban areas (Assah *et al*., 2015:701).

2.2.2 Determining physical activity levels

Numerous techniques can be employed to assess PA levels of an individual. Physical activity is assessed in order to give intensity, frequency, duration and type of behaviour per given time. Self-reporting tools for PA assessment include questionnaires, and PA logs and diaries (Ainsworth *et al*., 2015:389). Objective measures of PA include accelerometers, heart rate monitors and pedometers (Ainsworth *et al*., 2015:391). Choosing one mode over the other depends on the aim of the study. When selecting a method it is advisable to minimise the likelihood of measurement error and increase the precision of the assessment tool (Ainsworth *et al*., 2015:391). There are a number of factors to consider when selecting the method for PA assessment; these include cost, time, desired PA outcome, personnel available to assess PA and participants' characteristics (Ainsworth *et al*., 2015:391).

Each method of assessing PA has its own advantages and none is without flaws. The self-reported methods are more affordable and easy to complete. The disadvantage is the burden of having to carry a log book or diary during the day or having to remember detailed information at the end of the day (Ainsworth *et al*., 2015:389). Objective methods have different advantages and disadvantages depending on what is being used. Heart rate monitors are an excellent choice for swimming, cycling and other non-ambulatory activities. (Ainsworth *et al*., 2015:391). One of the limitations of this device is the need to account for blood pressure medication, and another is the discomfort of wearing the device for long periods of time (Ainsworth *et al*., 2015:391). Accelerometers are best for measuring PA in a detailed and relatively precise manner. There is minimal invasiveness, and the frequency, duration, pattern, and intensity of activity can be monitored over days, weeks, and even longer (Ainsworth *et al*., 2015:391). The main disadvantage of using an accelerometer is its inability to detect non-ambulatory activities, such as cycling and weightlifting. The device also lacks sensitivity on the sedentary and light intensity range of the activity spectrum (Ainsworth *et al*., 2015:391). The pedometer can effectively measure ambulatory activities during walking, jogging and running. Its shortfall is the inability to measure non-ambulatory activities, posture and energy expenditure (Ainsworth *et al*., 2015:390).

Poor levels of agreement exist between objectively measured PA and self-reported PA, with objective PA methods providing a more precise measure of PA (Lee *et al*., 2011:9; Skender *et al*., 2016:6; Steene-Johannessen *et al*., 2016:238). This is visible also in rural settings in Africa amongst majority black population (Wolin *et al*., 2008:750). Although self-reporting measures of PA show weak or poor association with objective measures of PA, they do, however, show potential in characterising PA levels and patterns in children and adolescents (Mciza *et al*., 2007:122). It is advisable that both measures be used in combination in order to give more detailed and a complete picture of PA, with self-reporting measures providing detail of the context and kind of PA performed (Sallis & Saelens, 2000:5; Skender *et al*., 2016:8).

There are numerous studies which have validated self-report PA questionnaires to ascertain that they can be effectively used in youth from different demographic, ethnic or cultural backgrounds (Craig *et al*., 2003:1388; Mciza *et al*., 2007:122; Sallis & Saelens, 2000:5; Scott *et al*., 2015:790). The International Physical Activity Questionnaire (IPAQ) can confidently be used as a method of measuring PA in both developed and developing countries (Craig *et al*., 2003:1388). Numerous methods can be employed for administering questionnaires and they include self-completing, face-to-face interviews and telephonic interviews (Booth, 2000:119). In general, however, interview methods appear to be a more accurate technique compared to the self-reporting method (Sallis & Saelens, 2000:5)

Table 2.1: Physical activity questionnaires validation against objective measures of physical activity

Questionnaire	Age (years)	Validated against	Study setting	Level of agreement	Authors
PAQ	9–12	ACTIVITYGRAM	South Africa	Weak	Mciza *et al*., 2007
IPAQ	16	Accelerometer	Vietnam	Poor	Lachat, C.K. *et al*., 2008
PAQA	16	Accelerometer	Vietnam	Poor	Lachat, C.K. *et al*., 2008
OPAQ	14	Accelerometer	Australia	Moderate/ Fair	Scott *et al*., 2015
IPAQ	15–17	Accelerometers	Europe	Moderate/ Fair	Hagstro¨mer *et al*., 2008
IPAQ	18–65	Accelerometer	Review article with 12 countries including South Africa	Good	Craig *et al*., 2003

IPAQ=International Physical Activity Questionnaire; OPAQ= Oxford Physical Activity Questionnaire; PAQ=Physical Activity Questionnaire

2.2.3 The health consequences of physical inactivity

The proposed PA levels are seen as a health-promotion and disease-prevention strategy (Martinez-Gomez *et al*., 2010:209; Strong *et al*., 2005:736; WHO, 2010:20). Lack of PA combined with sedentary behaviour has a detrimental effect on health status. Among other things, it causes overweight/obesity (Martinez-Gomez *et al*., 2010:201). Those who have low levels of PA are found to be more overweight than those with high PA levels (Muthuri *et al*., 2014:9; van Zyl *et al*., 2012:7). The presence of overweight gives rise to the risk factors of MetS in both children and adolescents (McMurray *et al.*, 2008:5; Pan & Pratt, 2008:284). The prevalence of MetS is much higher in overweight people compared to those with normal weight (Matsha *et al*., 2009:363; McMurray *et al.*, 2008:5; Pan & Pratt, 2008:284). MetS is linked to cardiovascular morbidity and mortality (Isomaa *et al.,* 2001:687).

There is strong evidence data which shows there is a beneficial effect of PA on musculoskeletal health, several components of cardiovascular health, adiposity and blood pressure in mildly hypertensive adolescents (Strong *et al*., 2005:736). Decreasing levels in PA will have detrimental consequences, possibly resulting in unfavourable health status. Physical inactivity causes up to 9% of premature death due to non-communicable diseases (Lee *et al*., 2012:6). By 2010, cardiovascular diseases, diabetes and cancer accounted for 26.6% of premature deaths reported in South African adults (Nojilana *et al.,* 2016:478). Risk factors that are associated with cardiovascular disease and type 2 diabetes start to manifest early in life (Steinberger *et al*., 2009:638)

Persons that currently do not meet the recommended daily dose of PA are advised to gradually start with small amounts of physical activity and gradually increase duration, frequency and intensity over time (WHO, 2010:18). Activities in which school age youth can participate in order to stay physically active include games, sports, walking, recreation, physical education, and planned exercise either at home, at school or in the community (WHO, 2010:18).

2.3 Metabolic syndrome

2.3.1 Pathophysiology of metabolic syndrome

It is necessary to understand the pathophysiology of MetS in order to effectively identify people at risk of cardiovascular diseases (Thaman & Arora, 2013:51). Emphasis should be placed on creating awareness on the pathophysiology, risk factors and prevention strategies of MetS in order to formulate treatment strategies for prevention of the disease. (Thaman & Arora, 2013:54). Environmental factors play a significant role in the development of MetS (Thaman &

Arora, 2013:51). Environmental triggers include physical inactivity, diet, age and hormonal changes, and ethnicity-related factors (Orho-Melander, 2006:22). Although lifestyle changes may be the driving force behind the increased prevalence of MetS, they are not the only factors that contribute to the development of the syndrome; genetic factors also contribute. Individual MetS traits are moderate to highly heritable (van Dongen *et al*., 2013). The unifying genetic factors that predispose MetS have not clearly been identified, however, several genes have been associated with at least two factors of MetS and are therefore considered the most promising candidate genes (Reilly & Rader, 2003:1546; Thaman & Arora, 2013:54).

Genetic factors play a role in the fat distribution in humans and are responsible for 70% of the variation in intra-abdominal fat mass (Shankar & Sundarka, 2003:287). Males are more affected by central fat distribution while females are more prone to peripheral fat distribution (Shankar & Sundarka, 2003:287). Insulin resistance or hyperinsulinaemia serves as the link between different components of MetS, it has a very strong connection with obesity, especially its central or visceral components. Insulin resistance is a physiological change that increases the risk of developing abnormalities such as dyslipidaemia, some degree of glucose intolerance, polycystic ovary syndrome and hemodynamic diseases. The body compensates for IR by increasing insulin secretion and that is referred to as hyperinsulinemia which greatly increases the chance of developing IR-related abnormalities (Reaven, 2002:288). In both adults and adolescents, IR is strongly associated with specific adverse metabolic factors (Weiss *et al*., 2004:2370).

2.3.2 Markers of metabolic syndrome

The components used in the diagnosis of MetS include: increased WC, elevated fasting triglycerides, elevated fasting glucose, elevated systolic blood pressure (SBP), elevated diastolic blood pressure (DBP) and decreased levels of high-density lipoprotein-cholesterol (HDL-C) (Corte *et al*., 2015:49).

2.3.2.1 Waist circumference and obesity

Waist circumference is often preferable in the classification of MetS compared to overweight/obesity. People with a large WC have higher levels of visceral adipose tissue, which is a key factor underpinning the dysmetabolic profile associated with abdominal obesity compared to persons with lower WC. Obesity and WC do not equally predict MetS, Waist circumference varies considerably for any given BMI range (Després *et al*., 2008:1044).

Even though overweight or obesity are not used in the diagnosis of MetS, abnormalities in the components of MetS are highly visible in obese adolescents from all around the world

(Kelishadi, 2007:69; McMurray *et al*., 2008:5; Misra & Khurana, 2008:12-13; Pan & Pratt, 2008:284). Being overweight or obese greatly increases the risk of acquiring MetS, and a high prevalence of overweight and obesity has been reported in South African children and adolescents (Rossouw *et al*., 2012:913; Monyeki *et al*., 2012:377). In the Tlokwe Municipality adolescents from both high and low SES showed a prevalence of overweight to be 13.7% (Monyeki *et al*., 2012:4).

Rural areas are no longer immune to the burden of overweight. In children and adolescents from rural Mpumalanga, there was a high prevalence of overweight. Overweight was reported in 18% of females and 4% of males (Kimani-Murage *et al*., 2010:6). Informal settlements too are stricken by the burden of overweight. In adolescents aged 10–17 years from Khayelitsha, Western Cape, the prevalence of overweight in 13–15 year olds was 10% and 9% in 10–12 year olds. Those aged 16 and above reported an overweight prevalence of 6% (Tsolekile *et al*., 2014:125).

Girls are the bigger contributors to the reported prevalence of overweight. Numerous studies have shown that girls are usually more overweight than boys (Kimani-Murage *et al*., 2010:6; Micklesfield *et al*., 2014:7; Monyeki *et al*., 2012:4). A possible reason for the high prevalence of overweight in girls compared to boys could be attributed to low levels of PA reported for girls (McVeigh & Meiring, 2014:375; Muthuri *et al*., 2014:3343; Shokrvash *et al*., 2013:7). In Mpumalanga adolescents, girls had a significantly higher prevalence of combined overweight and obesity than boys. Prevalence of overweight/obesity was 18% in females and 4% in males (Kimani-Murage *et al*., 2010:6). In another study also in Mpumalanga overweight was prevalent and more visible in girls (18.9%) than in boys (1.1%) (Micklesfield *et al.*, 2014:7).

2.3.2.2 High blood pressure

High blood pressure, which is one of the markers of MetS, is on the rise (Peltzer & Phaswana-Mafuya, 2013:68). As blood circulates through the body, it exerts pressure on the blood vessels. When the heart contracts the pressure is referred to as SBP and when it relaxes the pressure is termed DBP. When one or both of these pressures are consistently high the resulting condition is termed hypertension (WHO, 1996). Hypertension and high blood pressure are usually used interchangeably. Hypertension is associated with an increased risk of cardiovascular disease (Isoma *et al*., 2001:687), and can also lead to stroke due to small vessel (vascular) disease (Spence & Hammond, 2016: 49). It is not only high blood pressure that has a detrimental effect on health but also blood pressure at the upper limit of the normal; SBP:130–139 mmHg and DBP 85–89 mmHg are associated with cardiovascular events (Vasan *et al*., 2001:1293).

Physical inactivity, increased BMI, and age are the driving forces behind an increased prevalence of high blood pressure (Ataklte *et al*., 2015:294; Muluvhu *et al*., 2014:393; Murthy *et al*., 2013:347). In older people, the prevalence is much higher compared to the younger generation. The prevalence of hypertension in sub-Saharan African adults ranges between 14.7–69.9% (Ataklte *et al*., 2015:293). In a suburb in Durban, a hypertension prevalence of 47.5% was found (Prakaschandra *et al*., 2016:288), while over 60% of working adults in Potchefstroom were reported to be hypertensive (Ware *et al*., 2016:400). Hypertension, previously known to be an adult's condition, is increasingly becoming prevalent in adolescents. A high prevalence of hypertension was noted in adolescents from a peri-urban area in the Eastern Cape, where 21.2% of adolescents were found to be hypertensive (Nkeh-Chungag *et al*., 2015). For adolescents from an urban area in Johannesburg, Gauteng, the prevalence of pre-hypertension was 16.4% and hypertension was 14.8% (Kagura *et al*., 2015:3). Hypertension is also present in adolescents from the Tlokwe Municipality; in adolescents from both low and high SES the prevalence of pre-hypertension was 8.7% and that of hypertension was 4.3% (Awotidebe *et al*., 2015:247). Hypertension is more prevalent in boys than in girls (Awotidebe *et al*., 2015:247; Kagura *et al*., 2015:3). Hypertension in children and adolescence is linked to left ventricular hypertrophy (Brady *et al*., 2008:77; Richey *et al*., 2010:5) and is believed to track into adulthood if not corrected.

2.3.2.3 Dyslipidaemia

Dyslipidemia is a major constituent of MetS. It is defined as an abnormal lipid profile and is characterised by increased triglycerides and decreased levels of HDL-C (Reilly & Rader, 2003:1548). In the state of IR, there is an increased flux of free fatty acids from the periphery to the liver, the consequence of which is increased stimulation of hepatic triglycerides synthesis (Kolovou *et al*., 2005:360). Low HDL-C in MetS is secondary to raised triglycerides. High triglycerides levels result in a triglycerides-cholesteryl exchange between low-density lipoprotein (LDL-C) and very low-density lipoprotein (VLDL). The process is mediated by cholesteryl ester transfer protein. The exchange between LDL-C and VLDL-C results in the formation of triglyceride-rich HDL-C. The resulting molecule is prone to catabolism, hence low HDL-C in the case of increased triglycerides (Kolovou *et al*., 2005:361). Another mechanism that leads to reduced HDL-C levels is the reduced hepatic production of apo A in the state of IR. Apo A is the main protein component of HDL-C (Kolovou *et al*., 2005:361).

Central obesity and IR are the important markers that lead to the progression of dyslipidaemia (D'Adamo *et al*., 2015:6). The first line of treatment that can be used to treat dyslipidemia in MetS includes increased levels of PA, weight loss and low alcohol consumption (Kolovou *et al*., 2005: 364; Yoon, 2014:88). High levels of PA are correlated with reduced levels of triglycerides and increased levels of HDL-C (Yoon, 2014:88).

2.3.2.4 High glucose concentration and insulin resistance

High glucose levels or diabetes are markers of MetS and all lead to both microvascular and macrovascular complications. Microvascular complications are damages to the small blood vessels and include diabetic retinopathy, nephropathy and neuropathy (Flower, 2008:78). The presence of microvascular complication is a predictor of cardiovascular disease (Avogaro *et al*., 2007:1243). Macrovascular complications which are as a result of damages to large blood vessels include coronary artery disease, peripheral arterial disease and stroke (Flower, 2008:79). The central feature in macrovascular complication is the process of atherosclerosis which results in narrowing of the blood vessels (Flower, 2008:79).

High fasting glucose at childhood is carried into adulthood (Yajnik *et al.*, 2015:1630) and is associated with carotid intima-media thickness later in life, which depicts the extent of carotid atherosclerotic vascular disease (Yajnik *et al*., 2015:1630). Improvement in the glucose metabolism is brought about by changes in insulin activity that result in increased insulin sensitivity (Moraba *et al*., 2015:23).

Persistent IR throughout childhood to young adulthood has a higher cardiovascular disease risk (Yajnik *et al*., 2015:1634). Insulin sensitivity is profoundly influenced by genetic and acquired factors. Genetic defects that affect insulin sensitivity are relatively rare but they cause the most severe form of IR (Saltiel & Kahn, 2001: 803).

2.3.4 Diagnosis criteria and cut-off points for metabolic syndrome

There are different criteria for defining MetS but there is no single widely accepted definition (Jessup & Harrell, 2005:26; Thaman & Arora, 2013:54). Diagnosis applying the International Diabetes Federation criteria for any person between the age of 10–16 years stipulates the presence of central obesity (WC ≥ 90^{th} percentile, if lower then WC of > 80 cm in females > 94 cm in males can be used (Fernandez *et al.*, 2004:440), or if BMI is > 30 kg/m^2 central obesity can be assumed) and any two of the following: triglycerides ≥ 1.7 mmol/L, HDL-C < 1.3

mmol/L, glucose level > 5.6 mmol/L or blood pressure ≥ 130/85 mmHg (Zimmet *et al*., 2007:304).

When considering criteria from the National Cholesterol Education Programme/Adult Trial Panel III (NCEP/ATP III) for 12–19 year olds, the presence of three or more of the following components is required (WC ≥ 90th percentile for age and sex, triglycerides ≥ 1.24 mmol/L, HDL-C < 1.03 mmol/L, fasting glucose > 6.1 mmol/L and systolic or diastolic blood pressure > 90th percentile) (Corte *et al*., 2015:49). The American Heart Association criteria require that for a person to be classified as having MetS, central obesity as defined by WC of ≥ 90th percentile for age, sex and ethnicity must be present, plus any two of the following components: triglycerides ≥ 1.24 mmol/L, HDL-C ≤ 10th percentile for race and sex, glucose ≥ 5.6 mmol/L and blood pressure ≥ 90th percentile for age, sex and height (Corte *et al*., 2015:49).

WHO criteria is defined by one having diabetes mellitus, IR or impaired fasting glucose, and any two of the following conditions: blood pressure ≥ 140/90 mmHg, triglycerides ≥ 1.7 mmol/L, HDL-C < 0.9 mmol/L in men and < 1.0 mmol/L in women, central obesity as defined by waist: hip ratio > 0.90 males and > 0.85 females, or if BMI is greater than 30 kg/m^2, central obesity can be assumed, micro-albuminuria with urinary excretion rate ≥ 20 µg/min, albumin: creatinine ratio ≥ 30 mg/g (WHO, 1998:32-33).

NCEP/ATP III and IDF are preferred methods for diagnosing MetS since they provide simple syndrome markers whose relationship to CVDs has been established (Després *et al*., 2008:1041). Both the IDF and NCEP/ATP III are commonly used for diagnosis of MetS in adolescents (Silveira *et al*., 2013:3; Sewaybricker *et al*., 2013:69). The WHO is not a preferred diagnosis criteria in adolescents since abnormalities in glucose metabolism is compulsory for diagnosis of MetS to be made, and such abnormalities are normally only visible later in life (Sewaybricker *et al*., 2013:67). In adolescents, percentiles are used as cut-off points in most of the components rather than the absolute values used in adult populations (Jessup & Harrell, 2005:26).

Table 2.2: Different criteria for metabolic syndrome diagnosis

Markers	IDF	NCEP/ATP III	AHA
High-Density Lipoproteins	< 1.03 mmol/L in males, < 1.29 mmol/L in females	< 1.03 mmol/L	≤ 10^{th} percentile for race and sex
Glucose	≤ 5.6 mmol/L	> 6.1 mmol/L	≥ 5.6 mmol/L
Triglycerides	≥1.7 mmol/L	≥ 1.24 mmol/L	≥ 1.24 mmol/L
Waist Circumference	≥ 90^{th} percentile	≥ 90^{th} percentile for age and sex	≥ 90^{th} percentile for age, sex and ethnicity
Systolic Blood Pressure	≥ 85 mmHg	≥ 90^{th} percentile	≥ 90^{th} percentile for age, sex and height
Diastolic Blood Pressure	≥ 130 mmHg		≥ 90^{th} percentile for age, sex and height

IDF=International diabetes federation; NCEP/ATP III=National Cholesterol Education Programme/Adult Trial Panel III; AHA= American Heart Association

2.3.5 The prevalence of metabolic syndrome

The true prevalence of MetS varies widely across the world in different studies. This is due to a lack of universally accepted definitions of the syndrome which makes it difficult to compare prevalence between different studies (Shankar & Sundarka, 2003:275). Urbanisation and higher SES contribute to lower levels of PA and that seems to be the driving force behind the high occurrence of MetS (Assah *et al*., 2011:495). MetS is associated with an increased risk of cardiovascular morbidity and mortality in adults (Isomaa *et al.*, 2001:687). Steinberger *et al*., (2009:638) suggested that the risk factors associated with MetS manifest during early childhood.

A large pool of data reporting the prevalence of MetS in adults is available with studies in different settings reporting high prevalence (Erasmus *et al*., 2012:844; Motala *et al*., 2011:1033; Peer *et al*., 2015:1039). Although paucity exists in the data on children and adolescents regarding the prevalence of MetS, it was evident from the reviewed published data that the prevalence of MetS, though not expected in these stages of life, is high. A study of adolescents in the United States found the overall prevalence of MetS to be 3.5% (Pan & Pratt, 2008:283). In European adolescents, the prevalence was reported at 5.8% with the NCEP III criteria (Platat *et al*., 2005:2081). A total of 4.5% of American adolescents were diagnosed with MetS according to the IDF criteria (Ford *et al*., 2008:588). The prevalence of MetS in Canadian adolescents is 2.1% with the IDF criteria (Macpherson *et al*., 2016:34). Comparatively, in Africa, a population-based study on Egyptian adolescents found a prevalence of 7.4% with NCEP/ATP III criteria (Ella *et al*., 2010:191). Not all African countries report such high prevalence of MetS though; less than 2% of Mozambique adolescents were diagnosed with MetS (Dos Santos *et al.*, 2013:19). The two studies which could be found in South Africa were both from the Western Cape; in one study the prevalence of MetS was 1.9% with IDF and 6.5% with NCEP/ATP III criteria in 10–16 year olds (Matsha *et al*., 2009:363), while the results of the second study reported a 3.7% prevalence with NCEP/ATP III criteria for 15–18 year-old participants (Rensburg *et al.*, 2012:3).

Children and adolescents who are overweight or obese report the highest prevalence of MetS compared to those with normal weight. Numerous studies have indicated that the prevalence in the overweight category is more than double that found in the normal weight. Pan and Pratt, (2008:283) found a prevalence of 14.5% in overweight adolescents from the United States. Overweight European adolescents reported a prevalence of 26.2% (Platat *et al*., 2005:2081), while in South Africa Matsha and colleagues (2009:364) found a prevalence of 15.7% in overweight adolescents, and prevalence was even higher in those classified as obese (30.8%). This is a clear indication that an increase in the prevalence of overweight is parallel with an increase in the prevalence of MetS.

The literature reviewed shows that percentages differ in different studies, and one of the contributing factors is the application of different diagnostic criteria that do not give the same prevalence. It is evident from the literature that the NCEP/ATP III criteria give a MetS prevalence that is double that obtained by the IDF. Comparison between studies should, therefore, be made with caution. Another notable factor that brings about a difference in MetS prevalence is PA levels; studies that report high levels of PA report low occurrences of MetS compared to those that report low PA levels. Physical activity interventions should, therefore, be implemented to combat the prevalence of MetS in different settings.

2.3.6 Management of the metabolic syndrome

Lifestyle intervention is considered the first line of defence for the management and prevention of MetS. Lifestyle intervention includes a healthy diet, regular PA, psychosocial care and education. The main focus of the lifestyle intervention is to combat overweight/obesity and dyslipidaemia (Schwellnus *et al*., 2009:178). A healthy diet or nutritional intervention is aimed at reducing dietary fat intake, taking good carbohydrates with a low glycaemic index, limiting protein intake to about 15–20% of total diet. Limiting alcohol also seems to be very helpful as alcohol can raise blood pressure and increase triglycerides concentration as well as cause weight gain (Schwellnus *et al*., 2009:179). Lifestyle modifications that decrease the effect of IR can be beneficial as it has been reported as the link between all the components of MetS (Thaman & Arora, 2013:55). Other benefits include increased muscle glucose uptake, improved glycaemic control, improved lipid profile, reduced body weight, reduced blood pressure, positive effects on the thromboembolic state, and reductions in the overall cardiovascular risk (Schwellnus *et al*., 2009:180). To understand the impact of PA on the metabolic syndrome markers, each of the markers will be discussed in the next section.

2.4 The impact of physical activity on markers metabolic syndrome

2.4.1 Overweight and obesity

It is notable that overweight and obesity are associated with MetS, favourable adaptations of body weight are said to be induced by interventions such as PA programmes (Kelishadi, 2007:72; Vasconcellos *et al*., 2014:1150). Kenyan adolescents reported an overweight prevalence of 28.5% in those who reported less PA, in comparison to a prevalence of 14.7% of overweight in those that had high PA, largely attributed to active transport such as walking. Only 2.6 % of overweight adolescents met the recommended PA levels compared to 15.3% of the underweight and normal weight adolescents (Muthuri *et al*., 2014:9). Similarly, in adolescents in the Tlokwe Municipality, PA appears to be associated with overweight. Girls (39%) who reported lower levels of PA compared to boys (16.2%) showed the highest prevalence of overweight (32.4% in girls *vs* 17.1% in boys) (Toriola & Monyeki.2012:804). Furthermore, low levels of PA were found to be associated with large WC. European adolescents who did not achieve PA recommendations were 1.4 (95 % CI: 0.78-7) times more likely to have large WC than those who met the PA guidelines (Ortega *et al*., 2007:6). A systematic review investigating the effect of PA and body composition in adolescents reached a conclusion that PA is an effective tool to reduce high occurrence of overweight and central obesity (Vasconcellos *et al*., 2014:1149).

2.4.2 Insulin resistance

Insulin resistance or hyperinsulinaemia which a central feature of MetS can be managed through increased levels of PA. Higher PA levels are associated with lower insulin levels and low occurrence of IR when compared to low PA (Ferguson *et al*., 1999:893; Platat *et al*., 2005:2081; Reaven, 2002:288). An exercise intervention that continued for four months in adolescents resulted in a significant decrease in insulin levels from 155.5 pmol/l before the intervention to 140.6 pmol/l after the intervention $p<0.01$ (Ferguson *et al*., 1999:892). In adolescents of Tlokwe Municipality, it was determined that low levels of PA were associated with increased risk of IR, this was more visible in girls than in boys (Mamabolo *et al.*, 2014:194). Improvement in insulin activity leads to improved glucose metabolism. Insulin increases glucose transport in fat and muscle cells by the transporter GLUT4 (Saltiel & Kahn, 2001:800). Abnormalities in glucose metabolism or diabetes mellitus are usually presented later in life therefore, studies that report prevalence in children and adolescents are limited (Sewaybricker *et al*., 2013:67). Prevalence of pre-diabetes in the youth from Nigeria was reported at 4 % but it was however not found to be influenced by PA levels. Study revealed that poor diet as assessed by low fruit and vegetable intake (OR=1.45; 95 % CI 0.51–4.16; p=0.48) and overweight (OR = 2.91; 95 % CI 0.38–22.3: p = 0.30) were associated with pre-diabetes (Arigbede *et al*., 2016:3). Furthermore, the study used a questionnaire to collect PA information.Studies that use self-reporting measures of PA generally show weak association when PA is compared to MetS (Andersen *et al*., 2011: 873). This could explain why there was no association between PA levels and glucose.

2.4.3 Blood pressure

The benefits of regular PA are not only seen on body weight, dyslipidaemia and insulin levels, they also extend to blood pressure levels. The physiological effect of PA on cardiovascular markers includes increases in the heart rate, breathing and sweating, a slight reduction in tension levels, expansion of plasma volume, and an increase in maximal oxygen uptake (Monteiro & Filho, 2004:517). Studies that report low PA levels tend to report high levels of hypertension. In a study on South African adults in which more than half of the participants engaged in low PA, the overall prevalence of hypertension was high at 77.3% (Peltzer & Phaswana-Mafuya, 2013:68). The prevalence is not as high in studies that report high PA levels; this was evident in a study conducted on Kenyan adults where the overall prevalence of hypertension was 23% (Joshi *et al*., 2014:14). This trend is also visible in adolescents; a high prevalence of prehypertension and hypertension (32.3% and 4% respectively) was noted in the youth from Ghana, of which over 80% were reported to be physically inactive (Afrifa-Anane *et al*., 2015:4). Low levels of PA are associated with increased odds of high blood pressure. Portuguese adolescents who did not partake in leisure time PA were more likely (Odds ratio: 1.47;95% CI: 1.12; 1.93) to have high blood pressure than those that were active during their leisure time (Gaya *et al*., 2010:331). A previous study in a sample of adolescents in the Tlokwe Municipality reported that a 10-week PA intervention yielded a significant decrease in SBP in the intervention group (100; 95% CI: 97–102) compared to the control group (110; 95 % CI: 105–114) ($p < 0.01$). The intervention was performed three days a week for an hour. Sessions were comprised of a combination of aerobic exercises, sports specific exercise, strength and flexibility exercises (Zeelie *et al*., 2010b:156).

2.4.4 Dyslipidaemia

Physical activity has a positive effect on the lipid and lipoprotein concentrations (Strong *et al*., 2005:734). A review article that assessed the effect of PA and cardiovascular risk factors in children revealed that the association between PA and lipids (namely triglycerides, HDL-C, LDL-C and cholesterol) is generally weak, however, it is notable that PA has a beneficial effect on triglyceride and HDL-C levels. However, the relationship between PA and total cholesterol and LDL-C is inconsistent (Andersen *et al*., 2011: 872). A study on children from Finland found that PA is negatively associated with triglycerides ($\beta = -0.143$, $p = 0.002$) and positively associated with HDL-C ($\beta = 0.116$, $p = 0.013$) (Väistö *et al*., 2014:3). Casazza and colleagues (2009:17) also reported a similar trend in adolescents from the United States where PA was associated with triglycerides (−0.06974, $p<0.01$) and HDL-C (0.07680 $p<0.01$). Moderate PA of a minimum of 40 minutes per day at least five days a week that is sustained for at least four months is needed to improve lipid levels. This is required to induce or maintain these benefits (Andersen *et al*., 2011:873). It appears that the beneficial effects on blood lipids due to PA intervention follows an improvement in aerobic fitness (Andersen *et al*., 2011: 872). A study of adolescents revealed that diet was more closely related to markers of MetS than PA levels (Casazza *et al*., 2009:7). This could explain the weak association between PA and blood lipids.

2.4.5 Total prevalence of the metabolic syndrome

As mentioned previously, PA levels have a positive effect on the individual markers of MetS. However, the relationship between PA and MetS prevalence or score in adolescents is controversial. Studies have reported that high levels of PA are associated with low occurrences of MetS. A study on American adolescents showed that PA levels play a role in the prevalence of MetS; when these adolescents were grouped according to PA categories, those with low PA (4.3%) had the highest prevalence of MetS, followed by moderate PA (3.1%), and then high PA (2.6 %) (Pan & Prattt, 2008:279). Furthermore, a study on French adolescents reported that those with low PA levels tend to exhibit MetS more than those who report high PA levels (odds ratio=1.35; 95% CI: 0.56–3.26) (Platat *et al*., 2006:2081). Other studies have failed to detect this relationship, for example, in the youth from Mozambique no clear association was noted between PA and MetS (Dos Santos *et al*., 2013:20). Similarly, a study of adolescents in the United States found a poor association between PA and MetS (Casazza *et al*., 2009:9). The relationship between PA and MetS appears to be dependent on the method used to gather PA information. Studies using self-reporting methods for PA report no association or very little association between PA and MetS, however, those studies that make use of objective measures of determining PA report a more significant relationship (Andersen *et al*., 2011: 873).

Metabolic syndrome increases the risk of CVDs and diabetes mellitus, thus positive lifestyle changes promise to reduce the risk of CVDs and diabetes mellitus (Thaman & Arora, 2013:55). It is evident that PA is a primary prevention tool for CVDs (Warburton *et al*., 2006:801). It is an effective tool that can be used to prevent CVDs through favourable changes on its various markers. Compared to medication, PA has a low risk of side effects (Lin *et al*., 2015:19). The benefits of PA also extend to people who are already diagnosed with CVD (Warburton *et al*., 2006:801). Other modalities that can be used to lower the risk of CVDs include a healthy diet and drug treatment (Thaman & Arora, 2013:55).

2.5 Summary

The literature reviewed outlined the concepts that affirm that low PA and sedentary behaviour are related to overweight and obesity. The presence of overweight gives rise to the risk factors of MetS in both children and adolescents. Markers of MetS include a large WC measurement, overweight, dyslipidaemia, high blood pressure and glucose abnormalities. The literature further revealed that MetS is prevalent in both children and adolescents and that without prompt intervention it could be carried into adulthood. MetS has detrimental health effects; it is linked to cardiovascular morbidity and mortality. High PA levels reduce the odds of being diagnosed with MetS. Literature searches revealed that high PA levels have a positive effect on the individual markers of MetS. Studies recommend that children of school age should participate in 60 minutes or more of MVPA daily. The proposed PA levels are seen as a health-promotion and disease-prevention strategy. However, in Africa and abroad only a minority achieve these guidelines.

This chapter revealed that the consensus on the prevalence of MetS seems to be dependent on the criteria applied to define MetS. In adolescents, this is even more controversial, with scant evidence of which criteria to apply. The difference in the results obtained when different criteria are used influences the strategies to address the development and management of MetS. The lack of information with regard to the impact of PA on the risk factors of MetS further indicates that future research should focus on how applying the different diagnostic criteria within a South African context can influence the reported prevalence of MetS. Furthermore, it is also important that future research should determine the impact that regular PA has on the risk factors of MetS.

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CHAPTER 3

PREVALENCE OF THE METABOLIC SYNDROME IN SOUTH AFRICAN ADOLESCENTS ACCORDING TO IDF AND NCP/ATP III CRITERIA: THE PAHL-STUDY

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Abstract

***Objective*:** Determination of the prevalence of the metabolic syndrome (MetS) according to the International Diabetes Federation (IDF) and the National Cholesterol Education Programme/Adult Trial Panel III (NCEP ATP III) criteria among adolescents. Prevalence also determined in accordance with body mass index (BMI) categories.

Design: Data was drawn from the 2011 data collection of the Physical Activity and Health Longitudinal (PAHL) study which spans the years 2010-2014 with the aim to track changes in physical activity (PA) and markers of health in adolescents.

Setting and subjects: Adolescent girls and boys (n=215) aged 15 years from the Tlokwe Local Municipality, Potchefstroom, South Africa.

Outcome measures: Anthropometric measures and markers of the MetS.

Results: Prevalence of MetS in the sample population was 2.3% and 5.6% according to the IDF and NCEP/ATP III criteria respectively. MetS is significantly higher in overweight compared to normal weight group ($p<0.05$).

Conclusion: Prevalence of MetS is twice as high when the NCEP/ATP III cut-off point was applied, in comparison to the IDF criteria. Standardised cut-off points for South African adolescents should be derived for accurate identification of the MetS in this population. The observed prevalence of MetS warrants urgent strategic intervention given its public health implications.

Key words: Metabolic syndrome, Adolescents, Overweight/Obesity, NCEP ATP III, IDF.

Introduction

The metabolic syndrome (MetS) is associated with an increased risk of cardiovascular morbidity and mortality.[1,2] The clusters of risk factors that are associated with the MetS starts in childhood.[2] MetS is the consequence of a complex interplay between genetic and environmental factors.[3] Environmental triggers include physical inactivity, diet, age hormonal changes, and ethnicity-related factors.[4] Unifying genetic factors that predispose MetS have not been clearly identified.[3]

Over the years a plethora of criteria have been used for the diagnosis of MetS, with slightly different cut-off points.[5] The most common criteria used for the diagnosis of MetS include the International Diabetes Federations (IDF), National Cholesterol Education Programme/Adult Trial Panel III (NCEP/ATP III), World Health Organization (WHO), and American Heart Association criteria (AHA).[5,6] These criteria are mainly applicable in adults, although over the years these criteria have been modified for children and adolescents with their own specific cut-off points.[5,6] The components used in the diagnosis of MetS are the same for both children and adults but with slightly different cut-off points. The components include high waist circumference, elevated fasting triglycerides, elevated fasting glucose, elevated systolic blood pressure (SBP), elevated diastolic blood pressure (DBP) and decreased levels of high-density lipoprotein-cholesterol (HDL-C).[5]

The odds of obtaining MetS increases with low physical activity (PA) levels and the presence of obesity.[7,8] Numerous studies have shown that girls are heavier than boys.[9-11] Rural areas previously known to have low levels of overweight are now experiencing a burden due to the increase in overweight, which co-exist with underweight.[9] In the Tlokwe Municipality, adolescents from both high and low socioeconomic status (SES) are presented with a coexistence of underweight and overweight, more boys are underweight and more girls are overweight.[11] Insulin resistance or hyperinsulinemia serves as the link between different components of the MetS, and it has a very strong connection with obesity, especially its central or visceral components.[8] Numerous studies have shown that prevalence of MetS is higher in the overweight or obese when compared to normal weight.[12-14] It is more than double in the obese and overweight compared to the normal weight.[12,15] This clearly indicates that an increase in overweight or obesity is parallel to an increase in the prevalence of MetS.

Studies have been done in adults and they report high prevalence of MetS.[7,16-18] From the studies conducted in South African adult population, the prevalence has been reported as 31.7% according to the NCEP/ATP III criteria in blacks from townships around Cape Town.[19]

Additionally, results from a coloured population in the Bellville area of Cape Town, indicated that MetS was present in 60.6% of the participants according to the IDF criteria and in 55.4% of the participants according to the NCEP/ATP III criteria.[16] In rural Kwa-Zulu Natal the prevalence with IDF was 23.3% and higher in women compared to men.[17] In spite of available studies in adult population concerning the prevalence of MetS, there is paucity on adolescents. On European adolescents the prevalence was reported at 5.8% with the NCEP III criteria.[13] 4.5% of American adolescents where diagnosed with MetS according to the IDF criteria.[20] Prevalence of MetS in Canadian adolescents is 2.1% with the IDF criteria.[21] Comparatively in Africa, Population based study on Egyptian adolescents found a prevalence 7.4 % with NCEP/ATP III criteria.[22] Not all African countries report such high prevalence of MetS though, less than 2% of Mozambiquen adolescents where diagnosed with MetS.[23] The two studies which could be found in South Africa were in the Western Cape; in one study the prevalence of MetS was 1.9% with IDF and 6.5% with NCEP/ATP III criteria in 10-16 year olds.[12] The results from the second study reported a 3.7 % prevalence with NCEP/ATP III criteria for 15-18 year old participants.[24] Due to the large ethnically diverse groups in South Africa, determining the prevalence of MetS in adolescents of Tlokwe Municipality in the North West Province will add scientific knowledge to the scanty information currently available. The objective of the present study is therefore in twofold; to determine the prevalence of the MetS according to the 2007 pediatric International Diabetes Federation (IDF) and the National Cholesterol Education Programme/Adult Trial Panel III (NCEP ATP III) criteria among adolescents. Additionally, to determine the prevalence of MetS according to body mass index (BMI) categories for underweight, normal weight and overweight.

Methodology

Design

This study is an observational study of the Physical Activity and Health Longitudinal (PAHL) study that began in 2010 and continued until 2014. The aim of the overarching PAHL-study was to describe the changes in PA levels and the determinants of health risk factors in 14-18 year-old adolescents longitudinally. Details of the study and sample size are reported elsewhere.[11,25] The current study followed a cross-sectional design analysing data from the 2011 measurements to determine the prevalence of metabolic syndrome in adolescents aged 15 years from the Tlokwe Municipality in the North West Province of South Africa.

Demographics

The PAHL study was conducted in Tlokwe Local Municipality of the Dr Kenneth Kaunda District Municipality in the North West Province, South Africa. The Tlokwe municipality has a population of 162,762 of which 8.7% are between the ages of 15-19 years.[26] Black Africans are the majority of the inhabitants in the municipality followed by White Africans. Colored and Asians contributes the least to the population of the Tlokwe Municipality. Languages predominately spoken in the area include Setswana, Afrikaans and English.[26]

Participants

The study comprised of adolescents from six schools from a total of eight schools that were initially randomly selected to participate in the study. Two schools declined to take part in the study. From the six schools that agreed to take part, two were from a high socioeconomic area and the remaining four from a low socioeconomic area. From a total of 310 learners that agreed to take part in the PAHL study, 215 learners (both males and females) consented for blood sampling in 2011. The majority of the participants were blacks (Blacks n=150; Whites n=65), these group may not be considered to be a representation of the adolescent population in Tlokwe and South Africa as a whole.[26] The objectives, and potential risks and benefits of the study were explained to participants and their parents beforehand. Parents were asked for written consent and adolescents were also required to give verbal assent before participation. This study was approved by the research ethics committee of the North-West University (Ethics number: NWU-0058-01-A1).

Measurements

Body composition

Measurements of stature, body mass and hip and waist circumference were done by Level 2 criteria anthropometrists according to the standard procedure described by the International Society for the Advancement of Kinanthropometry.[27] Stature was measured to the nearest 0.1 cm using a stadiometer with participants' barefoot and standing upright with their head in the Frankfort plane. Body mass was measured to the nearest 0.1 kg with an electronic scale (Seca, Italy), with participants wearing minimal clothing. BMI was calculated using the formula weight divided by height in metre square. Cut-off points described by Cole et al[28, 29] were used to classify adolescents either as underweight, normal weight or overweight. A 7 mm flexible steel tape (Lufkin, Copper Tools, Apex, NC) was used to measure hip and waist circumference. Hip circumference was measured to the nearest 0.1 cm at maximum extension of the buttocks as viewed from the side. Waist circumference was also measured to the nearest 0.1 cm at the midpoint between the lower rib margin and the iliac crest. The cut-off points for waist circumference according to the IDF is ≥90th percentile for the whole population while for NCEP/ATP III it is ≥90th percentile for that age and gender. [30]

Blood pressure 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 blood pressure measurements were taken, talking was not permitted during the resting period, or when the blood pressure measurement was being taken. The average measurements from two separate measurements at least five minutes apart were used in the analysis.[31] A measurement of SBP >130 mmHg and DBP >85 mmHg was classified as abnormal according to the IDF cut-off point, and SBP ≥90th percentile[32] for whole population is considered abnormal according to the NCEP/ATP III criteria.

Blood sampling and analysis

Participants were asked to fast for 12 hours prior to blood collection. Blood samples were collected by a registered nurse in the morning with venous blood taken on the left arm from the brachio-cephalic vein into blood collecting tubes. The blood was centrifuged at 2000 rpm for 10 minutes, serum and plasma was then aliquoted into small Eppendorf tubes and stored at -84^{o} C until analysis by an accredited Pathology Laboratory was performed. Triglycerides, HDL-C and glucose levels were measured using DXC Unicell 600 Chemistry analyser manufactured by Beckman Coulter (Brea, California, USA). The system uses the timed endpoint method, measuring the change in absorbance (560 nm for HDL-C, 340 nm for glucose and 520 nm for triglycerides) and the change in absorbance is directly proportional to the analyte in the sample. The concentrations of the analyte were expressed in mmol/L.

Diagnosis of metabolic syndrome according to various cut-off points

The two criteria used for the classification of MetS in the current study are the IDF and NCEP/ATP III. Diagnosis of MetS with IDF criterion for any person between the ages of 10–16 years requires the presence of central obesity (high WC) plus any two or more of the risk factors. Diagnosis with NCEP/ATP III for adolescents between the ages 12-19 years requires three or more of the risk factors. The cut-off points for the risk factors are mentioned in table 1 below.[5,6]

Table 1: IDF and NCEP/ATP III criteria for classification of metabolic syndrome

Variable	IDF	NCEP/ATP III
HDL-C	< 1.03 mmol/L	< 1.03 mmol/L
Glu	≥ 5.6 mmol/L	> 6.1 mmol/L
Trig	≥ 1.7 mmol/L	≥ 1.24 mmol/L
DBP	≥ 85 mmHG	
SBP	≥ 130 mmHG	≥ 90^{th} percentile
WC	≥ 90^{th} percentile	≥ 90^{th} percentile for age and sex

IDF=International diabetes federation; NCEP/ATP III=National Cholesterol Education Programme/Adult Trial Panel III; HDL=High density lipoproteins Cholesterol; Gluc=Glucose; Trig=Triglycerides; DBP=Diastolic blood pressure; SBP; Systolic blood pressure; WC= Waist circumference.

Statistical analysis

Data was analysed using SPSS (IBM software Version 22). Descriptive statistics of mean and standard deviations (SD) were performed to describe the participants' characteristics for the total group, as well as separately for boys and girls. The prevalence of the MetS and the various components of the MetS were determined with frequency analyses reporting the percentage of adolescents with abnormal criteria for both IDF and NCEP/ATP III criteria separately. Mann-Whitney t-test and Chi-square were used to test the significant differences between the boys and girls and the IDF and NCEP/ATP III criteria respectively. Level of statistical significance was set at $p \leq 0.05$.

Results

Participant's characteristics are presented (Table 2) as mean and standard deviations for the total group and separately for boys and girls. Significant gender difference where noted for height, hip circumference, glucose and high density lipoprotein concentrations.

Table 2: Descriptive characteristics of participants

Variables	Total group (n=215)		Boys (n=86)		Girls (n=129)		p-values
	Mean	SD	Mean	SD	Mean	SD	
Age	14.85	0.83	14.89	0.75	14.82	0.87	0.55
Height (cm)	161.59	9.12	166.28	9.87	158.47	7.05	<0.01*
Body mass (kg)	55.65	13.06	57.70	14.19	54.29	12.11	0.60
BMI (kg/m^2)	21.18	3.95	20.67	3.83	21.52	4.01	0.12
WC(cm)	68.44	8.43	69.49	8.59	67.73	8.27	0.14
HC (cm)	90.01	11.41	87.18	9.66	91.91	12.11	<0.01*
DBP(mmHg)	67.30	7.60	67.33	8.29	67.28	7.14	0.97
SBP (mmHg)	102.06	9.69	103.86	10.99	100.85	8.54	0.25
Gluc (mmol/L)	4.87	0.47	5.01	0.48	4.78	0.43	<0.01*
Trig (mmol/L)	0.79	0.46	0.83	0.55	0.77	0.38	0.29
HDL-Chol (mmol/L)	1.29	0.34	1.21	0.32	1.35	0.34	0.02*
Insulin (µU/ml)	14.61	10.93	12.28	6.61	16.19	12.86	0.10

BMI=Body mass index; WC= Waist circumference; HC=Hip circumference; DBP=Diastolic blood pressure; SBP; Systolic blood pressure; Gluc=Glucose; Trig=Triglycerides; HDL=High density lipoproteins; SD=Standard deviation; * =statistically significant

Table 3: Prevalence of metabolic syndrome and risk factors of metabolic syndrome according to IDF and NCEP/ATP III criteria respectively

Variables	Total group (n=215)		Boys (n=86)		Girls (n=129)	
	IDF %	NCEP/ATPIII %	IDF %	NCEP/ATPIII %	IDF %	NCEP/ATPIII %
DBP (mmHg)	2.3		1.2		3.1	
SBP (mmHg)	0.9	65.1	2.3	12.8	0.0	0.0
Gluc (mmol/L)	5.6	0.5	10.5	1.2	2.3	0.0
HDL(mmol/L)	22.8	22.8	29.1	29.1	18.6	18.6
Trig (mmol/L)	3.7	12.6	4.7	15.3	3.1	10.9
WC(cm)	9.3	8.8	15.1	8.1	4.7	10.1
MetS	2.3	5.6	3.5	2.3	1.55	7.8

DBP=Diastolic blood pressure; SBP=Systolic blood pressure; Gluc=Glucose; HDL=High density lipoproteins; Trig=Triglycerides; WC=Waist circumference; MetS= Metabolic syndrome

Table 3 outlines the prevalence of MetS. MetS is prevalent in 2.3% of the participants according to the IDF criteria, and 5.6% according to the NCEP/ATP III criteria. The prevalence is higher in adolescent males compared to their female counterparts when the IDF criterion is applied. The opposite is true when the NCEP/ATP III criterion is applied. The difference in the prevalence between males and females is not statistically significant (IDF: p=0.37; NCEP/ATP III: P=0.09). According to the IDF criteria the percentage of males with abnormal glucose, triglycerides, systolic blood pressure, and waist circumference was higher compared to females. Even when the NCEP/ATP III criteria is applied, the majority of the risk factors in males are higher. Low HDL-C contributed the most to the prevalence of MetS in both categories. Low HDL-C was present in all the adolescents who were classified with MetS.

Table 4: Prevalence of metabolic syndrome when IDF and NCEP/ATP III criteria are applied respectively for different body mass index categories

BMI classification	N	IDF%	NCEP/ATP III%	p-value of the differences between weight categories
Underweight (<18.50 kg/m^2)	52	0	0	
Normal weight (18.50-24.99 kg/m^2)	133	0.8	2.3	<0.01
Overweight/obese (≥25.00 kg/m^2)	30	13.3	30	

BMI=Body mass index; IDF=International diabetes federation; NCEP/ATP III=National Cholesterol Education Programme/Adult Trial Panel III; n=Number of participants

The prevalence of MetS with both IDF and NCEP/ATP III criteria categorised by weight classification as determined by age specific cut-off points[28] (BMI) is presented in Table 4, it is higher in the overweight (≥25.00 kg/m^2) group. None of the participants categorised as underweight (<18.50 kg/m^2) presented with MetS for either classification criteria. The difference in the prevalence of MetS according to weight categories with either criteria is statistically significant (p<0.01).

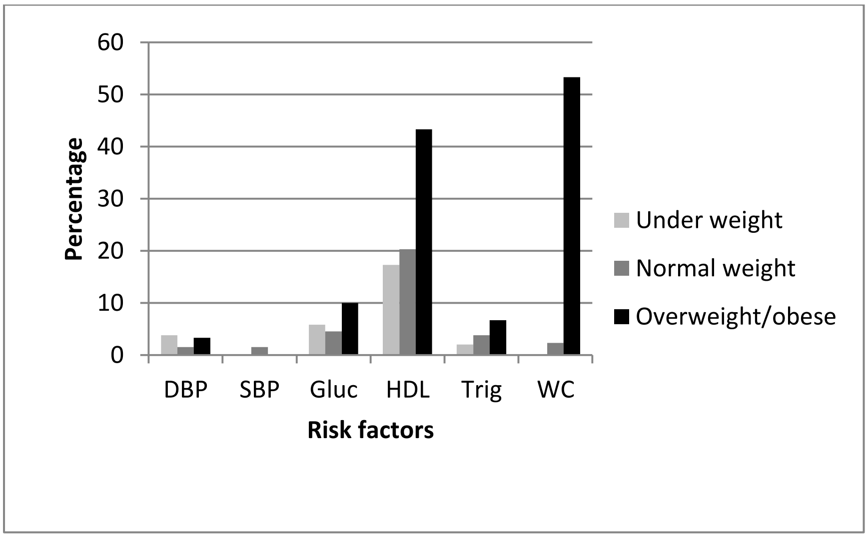

Figure 1: Prevalence of the risk factors of metabolic syndrome when IDF criteria is applied according to different body mass index categories

DBP=Diastolic blood pressure; Gluc=Glucose; SBP=Systolic blood pressure; Trig=Triglycerides; WC=Waist circumference

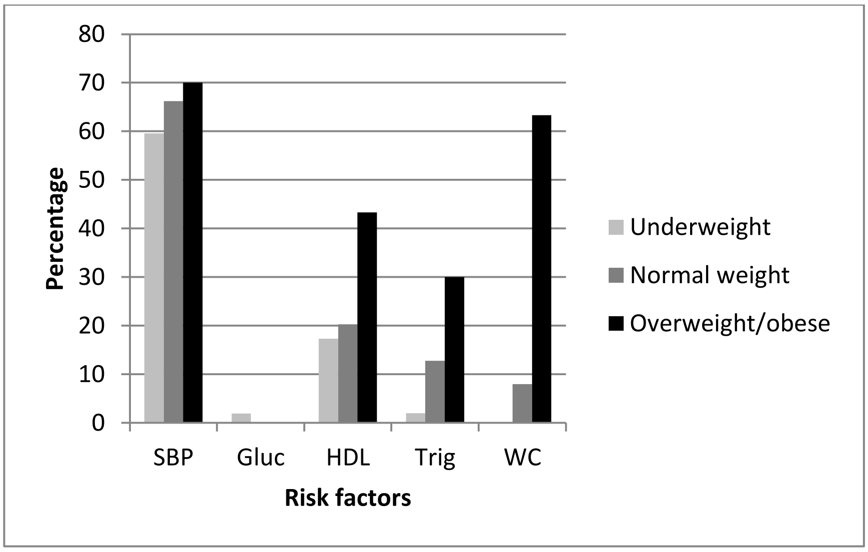

Figure 2: Prevalence of the risk factors of metabolic syndrome when NCEP/ATP III criteria is applied according to different body mass index categories

DBP=Diastolic blood pressure; Gluc=Glucose; SBP=Systolic blood pressure; Trig=Triglycerides; WC=Waist circumference

Figure 1 and 2 presents the percentages for the risk factors of MetS with both diagnostic criteria according to different weight categories. The overweight group present with higher percentages of the risk factors, whereas the underweight group shows lower percentages. Common risk factors with both diagnostic criteria include HDL-C and WC. With the NCEP/ATP III, SBP was more common.

Discussion

The aim of the study was to determine the prevalence of the MetS in adolescents residing in the Tlokwe Municipality of the North West Province, South Africa. The main finding of this study was that the prevalence of MetS by IDF definition and NCEP/ATP III is 2.3% and 5.6%, respectively. Furthermore, when the data was analysed separately for boys and girls, the results showed that girls had a higher (7.8%) prevalence of MetS with the NCEP/ATP III criteria compared to the boys (1.5%). Conversely, the boys (3.5%) showed a high prevalence of MetS when the IDF criterion was used compared to the girls (1.5%). The observed percentage difference may be explained by the higher mean for waist circumference in boys (69.49±8.59) compared to girls (67.73±8.27), as high waist circumference is a pre-requisite

for diagnosis of MetS using IDF criteria. The noted gender difference in the prevalence of MetS is however not significant (IDF: $p=0.37$; NCEP/ATP III: $p=0.09$). In addition, the results show that 7.9% and 22.9% (IDF and NCEP respectively) of the adolescents have two or more of the risk factors of MetS.

The two criteria used for diagnosis of MetS give different prevalence,[12] reason for this is the fact the IDF has high waist circumference as a pre-requisite which is not the case for NCEP/ATP III, which means that some of the adolescents with three risk factors or more were excluded merely because they have normal waist circumference. The inconsistency in the method of diagnosis of MetS is a cause for concern; selecting one criterion over another can result in either an under-estimation or over-estimation of the prevalence, which in turn may result in either inappropriate premature interventions or delayed intervention. Regardless of the inconsistency between the criterions, the prevalence of MetS in the current study remains high, and as such paints a troubling picture for these adolescents. MetS has been associated with an increased risk of cardiovascular morbidity and mortality in adulthood.[1] Unless strategies are implemented to address the risk factors in adolescents, the life expectancy and quality of life will be reduced due to the presence of long term risk factors for MetS.

The current status of the MetS in this study is evident in the assertion mentioned earlier by Steinberger *et al.*[2] that abnormalities in the risk factors are set to start early in one's life, and this therefore should be of concern given the fact that the youth are the cornerstone of the economy.[33] The observed prevalence of MetS in this study is in agreement with that reported in children and adolescents from around the world. The prevalence internationally is approximately 10%, ranging from 2% in the normal weight, up to 32% in the obese participants.[34] The wide range in the prevalence of MetS across the world is due to different criteria being applied in determining prevalence. No universally accepted definitions of MetS are available, in particular for adolescents, and this makes it difficult to compare prevalence between different studies.[8]

In a rural area in Mozambique, the adolescents were found to have a much lower prevalence of MetS reported at <2% in 7-15 year olds, and this was attributed to high levels of PA reported in these adolescents.[23] Comparatively, the prevalence in Mozambique is much lower when compared to that observed in our study. The differences in the prevalence between Mozambican children and South African adolescents under study may be explained by the fact that the majority (>60%) of adolescents in the Tlokwe Municipality do not meet the recommended 60 minutes per day of moderate-to-vigorous PA[35] Similarly, a study which was conducted amongst children aged 10-16 years from the Western Cape, South Africa, reported the prevalence of MetS to be 1.9% and 6.5% according to the IDF and NCEP/ATP III, respectively.[12]

Findings from a study in older adolescents from the Western Cape (15 and 18 years) reported a prevalence of MetS at 3.7% according to the NCEP/ATP III.[24] This prevalence is lower compared to the 5.6% reported in the current study on the adolescents attending schools in the Tlokwe Local Municipality. If no action is taken at this stage, the likelihood is that more risk factors may manifest and such manifestation is found to track very well from childhood to adulthood.[2,36] A study conducted on adults from Bellville in Cape Town reported a high prevalence of MetS of 60.6% using IDF criteria, and 55.4% according to the NCEP/ATP III.[15] In rural black adults from Kwa-Zulu Natal, the prevalence with IDF was 23.3% and 18.5% with ATP III.[17] Adolescents clearly present with a lower prevalence of MetS compared to adults.

Adolescents are becoming heavier as they age, with girls reported to be more overweight than boys.[9-11] Abnormalities in the components comprised in MetS are more visible in overweight adolescents.[12, 14] The data in this study confirms this; when the data was analysed according to weight categories, normal weight adolescents showed a prevalence of 0.8% (IDF) and 2.3% (NCEP/ATP III) respectively, and for the overweight group 13.3% (IDF) and 30% (NCEP/ATP III). MetS was not present in the underweight group. These observed results were similar to the findings of Tailor and colleagues who alluded that the prevalence of MetS ranges from 2% in the normal weight and 32% in the overweight/obese adolescents.[34]

Lifestyle intervention which is the first line of defence could be used to bring the prevalence of MetS down. This is possible through interventions that reduce body weight in overweight and obese persons with between 7-10 % of the person's body weight over a period of 6-12 months.[37] A diet low in saturated fat and simple sugars coupled with an increased intake of fruits, vegetables, legumes, and whole grain can help combat the high prevalence of MetS.[37] In order to improve cardiovascular and metabolic health biomarkers hence preventing MetS, it is recommended that school age youth participate in 60 minutes or more of moderate-to-vigorous PA daily or at least a minimum of three times a week. This proposed recommendation can be seen as a health-promotion and disease-prevention strategy.[38-40]

Limitations of the study include the sample size which is not representative of the whole population of adolescents in the Tlokwe Municipality. Future studies should determine the prevalence using a larger sample size that is representative of the adolescents in the Tlokwe Municipality or the North West Province. Adolescents included in the study were of the same age, therefore the results cannot be used to generalise across all ages of adolescence. Upcoming studies should include adolescents of all ages. Another limitation is the cross-sectional nature of the study which did not allow inference of causation; as such, longitudinal studies would provide more concrete evidence for this reason. The use of two widely accepted criteria in the diagnosis of MetS give different percentages, selecting one set of criteria over the other could result in either over- or under-estimations of MetS. This could potentially lead to either premature intervention or delayed interventions. A recommendation made from the current study is the determination of standardised consensus criteria for the classification of MetS in South African adolescents. When interpreting the current findings, lack of specific dietary or exercise intervention data should be taken into consideration.

Conclusion

The prevalence of metabolic syndrome is 2.5% and 5.6% in adolescents residing in the Tlokwe Municipality of the North West Province when the IDF and NCEP/ATP III criteria are applied respectively. The prevalence of MetS is six times higher in overweight adolescents. Variations in the prevalence of MetS are evident with the NCEP/ATP III criteria giving a prevalence that is twice as high compared to the IDF criteria. Standardised consensus criteria for MetS classification in adolescents is needed, along with intervention strategies to reduce the prevalence of the MetS at such an early age in order to prevent mortality and morbidity later in life.

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CHAPTER 4

RELATIONSHIP BETWEEN PHYSICAL ACTIVITY LEVELS AND METABOLIC SYNDROME MARKERS IN ADOLESCENTS FROM THE NORTH WEST PROVINCE: THE PAHL STUDY

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Abstract

Background: Coexistence of overweight/obesity and inactivity is associated with an increased risk of metabolic syndrome (MetS) in adolescents. The purpose of this study was to determine the relationship between physical activity (PA) and MetS markers in South African adolescents.

Methods**:** A total of 188 adolescents for the 2011 measurements wave of the Physical Activity and Health Longitudinal study (PAHLS) participated in this study. Physical activity levels (IPAQ-S) and markers of MetS were determined according to standard procedures. Classifications of MetS were according to the International Diabetes Federations (IDF) and The National Cholesterol Education Programme /Adult Trial Panel (NCEP/ATP III) criteria.

Results: Only 25% of the adolescents achieved the recommended ≥60 min/day MVPA. An inverse relationship between vigorous PA and diastolic blood pressure (DBP) ($r=-0.14$; $p=0.05$) was found. Though not significant, the odds of being diagnosed with MetS (NCEP/ATP III) when not meeting recommended PA guidelines is 2.4 times higher than if the PA guidelines are met. These findings were however not supported when the IDF criteria were applied.

Conclusion**:** High physical activity levels are negatively associated with DBP and can be used as one of the modalities to prevent or treat high blood pressure in South African adolescents.

Introduction

High levels of physical activity (PA) are associated with excellent health benefits. The reality is, however, that PA levels are declining rapidly leading to unfavourable health outcomes and premature death.[1] Low levels of PA and high levels of sedentary behaviour increase the risk of overweight and obesity in both children and adolescents. [2-5] Overweight and obesity is associated with an increased prevalence of metabolic syndrome (MetS), which is defined as a constellation of interconnected physiological, biochemical, clinical, and metabolic factors.[6] Risk factors of MetS include dyslipidaemia, elevated blood pressure and glucose levels and large waist circumference (WC).[7] Having these risk factors in combination increases the risk of atherosclerotic cardiovascular disease and Type 2 diabetes mellitus.[6,8]

Physical activity is a primary prevention tool for MetS markers.[9-12] Compared to medication, PA intervention has a low risk of side effects.[13] According to previous studies, a relationship exists between PA and markers of the MetS.[14,15] But whether PA levels can be used to predict the presence or absence of MetS is controversial. Some studies report that there is no clear relationship between PA and the prevalence of MetS [16,17] while others report the opposite. [3,18] PA is denoted as any bodily movement produced by skeletal muscles that results in energy expenditure.[19] It can be segmented into different categories depending on when and why it is performed. PA can be divided into sleeping activity, work PA, commuting PA and leisure time PA. [19] In order to achieve health benefits and prevent disease, there are PA recommendations that should be followed. [20-22] Numerous studies recommend that school-aged youth should participate in 60 minutes or more of moderate-to-vigorous PA (MVPA) daily. [20-22] Adults, on the other hand, should engage in at least 150 minutes of moderate-intensity aerobic PA throughout the week.[22]

Even though it is clearly evident that a high level of PA is one of the methods that yields health benefits, PA is still insufficient and thus remains a problem that affects people from both urban and rural areas.[23-26] It is however slightly higher in rural areas compared to urban areas in countries such as Cameroon, Mozambique, South Africa and Kenya. [16,25, 27, 28,] In both adults and adolescents, males are generally more active than females and PA decreases with age. [2,24,25,29] PA trend analysis in ten Eastern Mediterranean countries showed that only 19% adolescents aged 13–15 years from a school-based study met the recommended PA level, of which the boys contributed greatly to the percentage.[30] In Kenyan adolescents, more boys (17.6%) than girls (8.3%) met the recommended PA criteria.[25] In South Africa, a Healthy Kids Report Card from 2014 indicated that on average only about 50% of adolescents are adequately active and girls are more prone to insufficient activity than boys.[31] In the Tlokwe Municipality, although the study sample was not statistically representative of adolescents in the area, only 36% of participants achieved the recommended MVPA of 60 minutes per day.[26]

A decrease in PA levels is usually coupled with an increase in sedentary behaviour.[32] Sedentary behaviour implies participation in activities that involve energy expenditure of less than 1.5 metabolic equivalents (METs). [33] Sedentary behaviour includes activities such as lying in bed, watching television (TV), and playing computer games. South African adolescents on average spend three hours a day watching TV on weekdays and the time increases to 3.5 hours on weekends. [31] Consequently, sedentary behaviour, as with low levels of PA, is a contributory factor to the MetS.[34]

Sedentary behaviour is a contributing factor to obesity or overweight. [30] A high prevalence of overweight and obesity has been reported in South African children and adolescents.[28, 35] There is a coexistence of overweight/obesity and low PA levels in adolescents in the Tlokwe Municipality of the North West Province. Previous research in this population indicated that girls had an obesity prevalence of 17% and boys 8% (28). MetS is high in prevalence around the world.[16, 36-39] Strategies that are aimed at reducing overweight and obesity (such as increased PA), have been shown to lower the prevalence of MetS. Promotion of PA at an early age that seeks to prevent overweight and obesity might be the best tool to lower the risk of developing MetS. [10-12,40]

More than 60% of adolescents in the Tlokwe Municipality are not adequately physically active.[26] The prevalence of MetS in these adolescents is found to be 2.3% according to classification by the International Diabetes Federations (IDF), and 5.6% using the classification according to the National Cholesterol Education Programme /Adult Trial Panel (NCEP/ATP III) criteria. [41] However, it is not known how PA relates to the markers of MetS in these adolescents. Studies designed to assess the relationship between PA and MetS in South African adolescents are scanty. A previous study in a sample of adolescents from the same area reported that a 10-week PA intervention resulted in a significant decrease in systolic blood pressure (SBP). Changes in lipid patterns as a result of the PA intervention was however not reported.[14] Based on the presiding literature information, the aim of the current study was therefore to determine the relationship between PA and markers of MetS in adolescents. The study will also determine the relationship between PA and the prevalence of MetS.

Methodology

Design

This study is part of an observational study on the Physical Activity and Health Longitudinal (PAHL) study that began in 2010 and continued until 2014. The aim of the overarching PAHL study was to longitudinally describe the changes in PA and the determinants of health risk factors in 14–18 year-old adolescents. Detail of the study is reported elsewhere.[28] The current study, therefore, followed a cross-sectional design on the 2011 measurements to determine the relationship between PA and markers of MetS in adolescents aged 15 years from the Tlokwe Municipality in the North West Province of South Africa.

Demographics

The PAHL study was conducted in Tlokwe Local Municipality of the Dr Kenneth Kaunda District Municipality in the North West Province, South Africa. The Tlokwe municipality has a population of 162,762 of which 8.7% are between the ages of 15-19 years.[26] Black Africans are the majority of the inhabitants in the municipality followed by White Africans. Colored and Asians contributes the least to the population of the Tlokwe Municipality. Languages predominately spoken in the area include Setswana, Afrikaans and English.[26]

Participants

Participants comprised learners attending six different high schools, two of which were from a high socioeconomic area, with the remaining four from a low socioeconomic area. From a total of 310 learners who agreed to take part in the PAHL study, 188 (both males and females) gave informed consent for blood sampling in the 2011 data collection wave. The majority of the participants were blacks these group may not be considered to be a representation of the adolescent population in Tlokwe and South Africa as a whole. The objectives, potential risks and benefits of the study were explained to participants and their parents beforehand. Parents gave written consent and adolescents were also required to give verbal assent before participation. This study was approved by the research ethics committee of the North-West University (Ethics number: NWU-0058-01-A1)

Measurements

Body composition

Measurements of stature, body mass, circumference and skinfolds were performed by Level 2 criteria anthropometrists according to the standard procedures described by the International

Society for the Advancement of Kinanthropometry.[42] Stature was measured to the nearest 0.1cm using a stadiometer with participants being barefoot and standing upright with their head in the Frankfort plane. Body mass was measured to the nearest 0.1kg with an electronic scale (Seca, Italy), with participants wearing minimal clothing. Body mass index (BMI) was calculated by dividing the body mass by stature in square metres (kg/m^2). A 7mm flexible steel tape (Lufkin, Copper Tools, Apex, NC) was used to measure hip and waist circumferences. Hip circumference (HC) was measured to the nearest 0.1cm at maximum extension of the buttocks as viewed from the side. Waist circumference was measured to the nearest 0.1cm at the midpoint between the lower rib margin and the iliac crest. The cut-off points for WC which are age and gender specific, were determined by the IDF ($\geq 90^{th}$) and NCEP/ATP III ($\geq 90^{th}$).

Blood pressure measurement

Measurements were taken on the left arm using Omron MIT Elite Plus (Omron Healthcare Co. Ltd., Japan). Participants were asked to lie down and rest for five minutes before blood pressure measurements were taken, talking was not permitted during the resting period nor when blood pressure (i.e. systolic and diastolic blood pressure) measurement were taken. The average measurements from two separate measurements at least five minutes apart were used in the analysis.[43] A measurement of > 130/85 mmHg was classified as abnormal according to the IDF cut-off points, and systolic blood pressure $\geq 90^{th}$ percentile for the whole population was considered abnormal according to the NCEP/ATP III criteria.[7]

Blood sampling and analysis

Participants were requested to fast for twelve hours prior to blood collection. Blood samples were collected by a registered nurse in the morning with venous blood taken on the left arm from the cephalic vein into blood collecting tubes. The blood was centrifuged at 2,000rpm for 10 minutes, serum and plasma were then aliquoted into small Eppendorf tubes and stored at -84^{o} C until analysis by an accredited pathology laboratory was performed. Triglycerides, high-density lipoprotein cholesterol (HDL-C), and glucose levels were measured using a DXC Unicell 600 Chemistry analyser manufactured by Beckman Coulter (Brea, California, USA). The system uses the timed endpoint method, measuring the change in absorbance (560nm for HDL-C, 340nm for glucose and 520nm for triglycerides). The change in absorbance is directly proportional to the analyte in the sample. The concentrations of the analyte were expressed in mmol/L.

Diagnosis of metabolic syndrome according to various cut-off points

The IDF criteria and the NCEP/ATP III that were used for MetS classification in the current study are indicated in Table 4.1.[7, 44]

Table 1: IDF and NCEP/ATP III criteria for classification of metabolic syndrome

Variable	**IDF**	**NCEP/ATP III**
HDL-Cholesterol	< 1.03 mmol/L	< 1.03 mmol/L
Glucose	≤ 5.6 mmol/L	> 6.1 mmol/L
Triglycerides	≥ 1.7 mmol/L	≥ 1.24 mmol/L
Diastolic Blood Pressure	≥ 85 mmHg	
Systolic Blood Pressure	≥ 130 mmHg	≥ 90^{th} percentile
Waist Circumference	≥ 90^{th} percentile	≥90^{th} percentile for age and sex

IDF=International Diabetes Federation; NCEP/ATP III=National Education Cholesterol Programme/Adult Trial Panel III; HDL= High-density lipoproteins cholesterol

Physical activity levels determination

Physical activity levels were determined using the short form of the International Physical Activity Questionnaire (IPAQ).[45-47] The questionnaire consisted of seven questions which asked the participants about the frequency and time spent sitting, walking and MVPA during the previous seven days. Sessions which lasted ten minutes or longer were considered.

Total PA in metabolic equivalent (MET) score was calculated as (Total MET-min/week = (Walk METs*min*days) + (Moderate METs*min*days) + Vigorous METs*min*days) scores for moderate-to-vigorous, walking and sitting activities in the last seven days. Subsequently, MVPA daily was computed according to the following equation; MVPA daily = (Moderate METs.min/week + Vigorous METs.min/week)/7. Scores ≥60 min/day indicates that PA guidelines have been achieved while below this means that the PA recommendations have not been met.

Statistical analysis

Data was analysed using SPSS (IBM software Version 23). Descriptive statistics reporting the means and standard deviations (SD) were determined for the participant characteristics for the risk factors of MetS, while the median and interquartile range (25–75th) were made to describe the PA categories of the participants for the total group, and separately for boys and girls. Participants were further grouped according to 'meeting the PA recommendations' and 'not meeting the PA recommendations'. The relationship between PA and MetS markers was determined by means of Pearson's Moment coefficient (r) correlation for parameters that were normally distributed (DBP and SBP). For parameters not normally distributed the Spearman correlation was performed (Glucose, HDL-C, triglycerides, WC, moderate PA, vigorous PA, walk PA, total PA, MVPA daily). To determine the odds of being classified for MetS according to level of PA, cross tabs were performed and odds ratios determined with 'not meeting the PA recommendations' as the reference. Level of statistical significance was set at $p \leq 0.05$.

Results

Table 2 outlines participant's characteristics as mean and standard deviation for whole group and for boys and girls separately to observe gender differences.

Table 2: Descriptive characteristics of participants

Variables	Total group (n=188)		Boys (n=75)		Girls (n=113)		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	***p***
Age (years)	14.82	0.86	14.87	0.79	14.78	0.90	0.52
Height (cm)	161.60	9.29	166.96	9.76	158.04	7.01	0.00*
Body mass (kg)	54.88	12.34	57.57	12.95	53.09	11.64	0.06
BMI (kg/m^2)	20.88	3.64	20.46	3.29	21.16	3.86	0.20
WC (cm)	67.85	7.84	69.12	7.63	67.01	7.90	0.07
HC (cm)	89.33	11.25	86.78	8.93	91.02	12.31	0.01*
DBP (mmHg)	67.26	7.60	67.65	8.43	67.00	7.02	0.57
SBP (mmHg)	102.21	9.99	104.33	11.30	100.81	8.80	0.01*
Glucose (mmol/L)	4.88	0.47	5.04	0.46	4.77	0.44	0.00*
Triglycerides (mmol/L)	0.77	0.37	0.81	0.38	0.73	0.35	0.13
HDL-Chol (mmol/L)	1.30	0.34	1.19	0.31	1.37	0.34	0.01*
Insulin (µU/ml)	14.79	11.37	12.49	6.76	16.34	13.45	0.00*

BMI=Body mass index; WC=Waist circumference; HC=Hip circumference; DBP=Diastolic blood pressure; SBP=Systolic blood pressure; HDL=High-density lipoproteins; SD=Standard deviation; METs=Metabolic equivalents; MVPA=Moderate-to-vigorous physical activity; HDL-Chol=High-density lipoproteins cholesterol, * $p \leq 0.05$ for between genders

A total of 188 adolescents participated in the study. Significant gender differences where noted for height, hip circumference, HDL-C, SBP, insulin, and glucose concentrations.

Table 3: Median and interquartile ranges of physical activity parameters for total group and separately for boys and girls

Variable	Median (IQR)	Median (IQR)	Median (IQR)
	Total group	Boys	Girls
Mod (MET.min/week)	28.00(28-335.00)	64.00(28-400)	28.00(28-335.00)
Vig (MET.min/week)	52.00(18.00-480)	112.00(36.00-600)	52.00(18.00-480.00)
Walk (MET.min/week)	23.10(23.00-279.38)	44(23.10-330.00)	23.10(23.1-276.38)
Total PA (MET.min/week)	97.00(51.10-876.00)	240.00(51.1-876.00)	51.10(24.00-650.25)
MVPA daily (min)	4.00(1.71-59.29)	4.00(0.00-65.14)	4.57(2.86-58.57)

IQR=Interquartile range; MET.min/wk= Metabolic equivalents minutes per week; Mod PA=Moderate physical activity; Vig PA=Vigorous physical activity; MVPA=Moderate-to-vigorous physical activity

Table 3 presents the median and interquartile range (25-75 th) of PA parameters of adolescents for total group and for girls and boys separately.

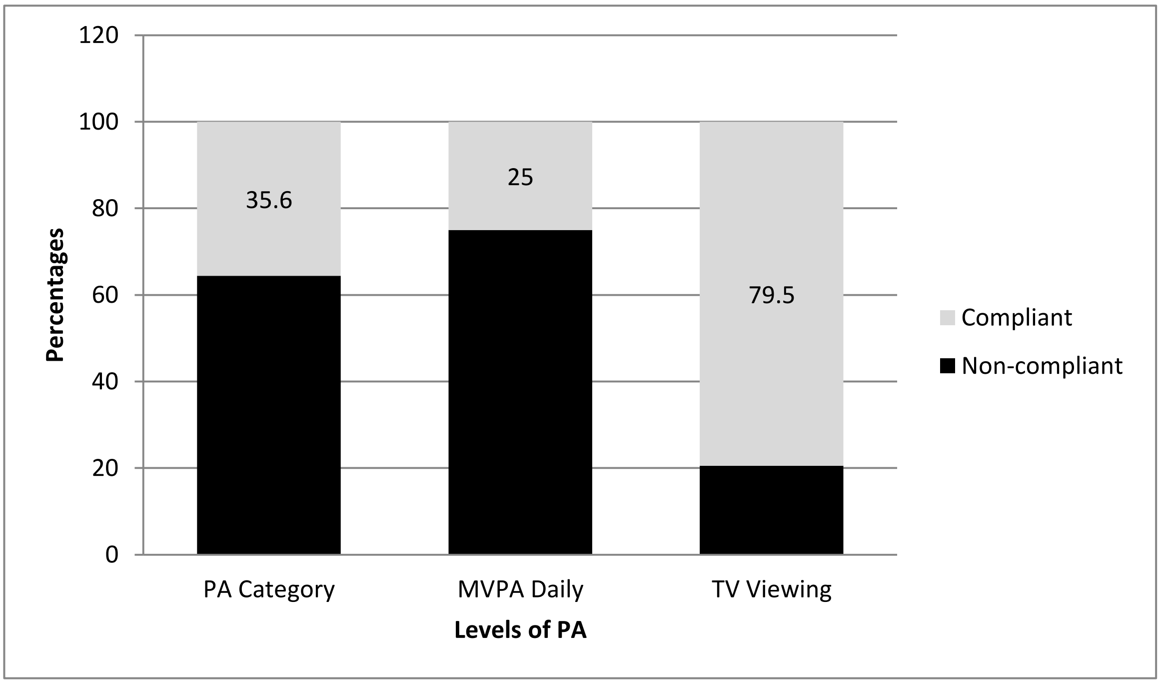

Figure 1: Descriptive characteristics of categorical data of physical activity

MVPA= Moderate to vigorous physical activity; PA=Physical activity; TV=Television

Figure 1 presents the descriptive characteristics of categorical data of PA. Only 25% achieved the recommended ≥60 min MVPA per day. The majority of adolescents reported low PA compared to only 35.6% who reported moderate-high PA. The percentage of adolescents who spend three hours per day or more watching TV was reported at 20.5%, with the remainder spending less than three hours.

Table 4: Descriptive characteristics of markers of metabolic syndrome from participants (n=188) classified according to meeting physical activity recommendations

Variables	**Meeting PA recommendations Mean(SD)**		***p* value**
	Yes	**No**	
Triglycerides (mmol/L)	0.81 (0.47)	0.75 (0.32)	0.26
Glucose (mmol/L)	4.89 (0.46)	4.88 (0.47)	0.92
HDL-Chol (mmol/L)	1.30 (0.35)	1.30 (0.34)	0.91
Insulin (μU/ml)	16.94 (11.43)	14.06 (11.30)	0.13
BMI (kg/m^2)	20.56 (2.89)	20.99 (3.87)	0.48
Body Mass (kg)	54.21 (10.60)	55.11 (12.91)	0.67
WC(cm)	66.91 (5.90)	68.17 (8.39)	0.34
HC (cm)	87.70 (15.09)	89.87 (9.66)	0.25
DBP(mmHg)	66.06 (7.42)	67.66 (7.65)	0.21
SBP (mmHg)	100.81 (9.58)	102.68 (10.12)	0.27

BMI=Body mass index; WC= Waist circumference; HC=Hip circumference; DBP=Diastolic blood pressure; SBP=Systolic blood pressure; HDL-Chol=High-density lipoproteins cholesterol; SD=Standard deviation

Table 4 shows the characteristics of the MetS markers when participants were categorised according to meeting or not meeting the recommended MVPA levels. There was no significant difference in the MetS markers between participants who achieved recommended PA levels compared to those who did not meet the recommended requirements.

Table 5: The relationship between physical activity and markers of metabolic syndrome

Markers of MetS	Moderate PA (MET.min /wk)		Vigorous PA(MET.min /wk)		Walking (MET.min /wk)		Total PA (MET.min/wk)		MVPA daily minutes	
	r	*p*	*R*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Trig (mmol/L)	0.11	0.15	-0.07	0.35	0.11	0.15	0.07	0.37	0.05	0.50
Gluc(mmol/L)	0.09	0.24	-0.10	0.19	0.09	0.24	-0.00	0.99	-0.03	0.77
HDL(mmol/L)	0.06	0.44	-0.07	0.34	0.06	0.44	0.01	0.88	-0.01	0.87
BMI (Kg/m^2)	-0.04	0.60	-0.04	0.55	-0.04	0.06	-0.09	0.24	-0.09	0.21
WC(cm)	0.01	0.86	-0.05	0.46	0.01	0.86	-0.05	0.51	-0.06	0.11
DBP(mmHG)	-0.03	0.75	**-0.14**	**0.05**	-0.03	0.75	-0.09	0.22	-0.12	0.11
SBP (mmHG)	-0.04	0.59	0.00	0.95	-0.04	0.59	-0.04	0.63	-0.02	0.70

BMI=Body mass index; WC= Waist circumference; HC=Hip circumference; DBP=Diastolic blood pressure; SBP=Systolic blood pressure; HDL=High-density lipoproteins; SD=Standard deviation; METs=Metabolic equivalents; MVPA=Moderate-to-vigorous physical activity

The results obtained for determining the relationship between PA level and markers of MetS are presented in Table 5. The only significant relationship between markers of MetS and PA level was found for DBP, which indicated a significant negative relationship with vigorous PA (r = -0.14; p =0.05).

Table 6: Odds ratio of having metabolic syndrome when not meeting the recommended physical activity guidelines

		95% Confidence Interval		*p* value
	OR	Lower	Upper	
IDF criteria	1.00	0.102	9.852	0.69
NCEP/ATP criteria	2.40	0.288	20.057	0.36
No of Cases	188			

MetS=Metabolic syndrome; IDF=International Diabetes Federations; NCEP/ATP III=National Education Cholesterol Programme/Adult Trial Panel III; MVPA=Moderate-Vigorous physical activity; PA=Physical activity; OR= Odds ratio

The odds of being diagnosed with MetS (NCEP/ATP III) when not meeting recommended PA guidelines is 2.40 times higher than when meeting the PA guidelines. These findings were not supported when the IDF criteria were applied, however, these findings were not significant.

Discussion

The current study aimed to determine the relationship between PA and markers of MetS in adolescents when the IDF and NCEP/ATP III criteria are applied. The main findings of this study indicated that 25% of the adolescents met the current PA guidelines of 60 min/per day of MVPA. Only DBP as a marker of MetS indicated a significant inverse relationship with vigorous PA levels. Furthermore, the study findings revealed that there was no significant difference in the MetS markers of adolescents who achieved the PA recommendations compared to adolescents who did not. MetS diagnosed with NCEP/ATP III is 2.4 times more likely when not achieving the PA guidelines compared to achieving the PA guidelines, however, these findings are not significant.

Adolescents around the world are not active enough, with large percentages not meeting the PA guidelines. Only 19%, 33% and 12% of Eastern Mediterranean, Irish and Kenyan adolescents respectively achieved the recommended PA guidelines .[23, 25, 30] South African adolescents are no different; the majority do not meet the guidelines. Percentages of adolescents meeting the guidelines in different studies are <1%, 26% and 36% from KwaZulu-Natal, Mpumalanga and North West Province respectively.[26, 48, 49] The current study supports the lack of sufficient PA in adolescents with a quarter of the participants not fulfilling the recommendations. Wushe et al[26] reported that only 36% of the same cohort with data at age 16, met the PA guidelines with an objective measurement of PA. Differences in the prevalence can be explained by the use of different methods applied for gathering PA information. Wushe *et al*[26] use combined accelerometer and heart rate devices (Actiheart) while the current study used IPAQ-S.

Hypertension, a marker for MetS, which used to be prevalent only in urban areas, [50] is now becoming prevalent in rural areas. A rural area in Limpopo province reported the prevalence of hypertension in adults at 41.4% with a higher percentage having isolated elevated DBP than elevated SBP.[51] Hypertension seems to be on the rise in adolescents too; a high prevalence of hypertension was noted in adolescents from a peri-urban area in the Eastern Cape where 21.2% of adolescents were found to be hypertensive.[52] Hypertension has also been previously reported in adolescents of the Tlokwe Municipality at 4.3%. A higher occurrence of hypertension is associated with lower levels of PA. [53, 54] In the current study DBP was the only MetS marker that showed a significant inverse relationship with PA measures. Zeelie et al [14] reported a positive effect of PA intervention on the blood pressure of South African adolescents, however, it was only SBP measurements that significantly changed. DuBose et al[15] reported results similar to the current study, where DBP was the only MetS risk factor negatively associated with PA levels (this was in children and adolescents from the United States).

The relationship between PA and MetS is not always clear. In some studies, the relationship between PA and MetS markers is reported but does not include all the markers. [14, 15] It is, however, also not clear in the literature what the relationship between PA and the MetS score is, nor its prevalence. A study by Casazza et al[17] reported associations between PA and some of the individual markers, including HDL-C and triglycerides, but did not find an association between PA and MetS. A study on Mozambique adolescents also did not find any clear association between PA and MetS. [16] Other studies though have found a clear relationship between PA and MetS, showing that high PA is associated with a low occurrence of MetS. [3, 18] This study found that by not achieving the 60 min/day MVPA, MetS is 2.40 (95% CI: 0.29; 20.06) more likely than when achieving the PA guidelines. This was noted when MetS was diagnosed with NCEP/ATP III, but when using the IDF criteria to diagnose MetS, there was no clear relationship. This highlights the fact that selecting one criterion over the other presents discrepancies in results, however, these findings were not significant.

There are a number of reasons that could explain the lack of a significant relationship between PA and other markers of MetS; one of them could be due to the low levels of PA reported in this group, as adolescents in this area are highly inactive. The MetS present in these adolescents may not solely be due to physical inactivity but also the increased circulating levels of insulin. Increased prevalence of insulin resistance is strongly associated with an increased risk of developing MetS.[3, 4, 11] The odds of being classified as having MetS when not meeting the PA guidelines compared to meeting the guidelines, reveals large discrepancies between the applications of the two internationally accepted criteria. Meeting PA guidelines did not have any significant impact on MetS, Standardised cut-off points for South African adolescents should be derived for accurate identification of MetS in this population, and this might assist in determining the relationship between PA and MetS without reasonable doubt. Another reason why these findings were not significant could be due to the method employed to determine PA levels in the study. Though self-reporting measures of PA show potential in characterising PA levels, poor levels of agreement exist between these methods and objective measures in rural African settings. Objective measures appear to be more reliable.[55] A sedentary lifestyle independent of PA levels increases the risk of MetS. [34] In the current study, 20.5% of adolescents spend three hours or more watching TV, and this may also contribute to MetS. Diet, which was not assessed in the current study may also have had an effect, hence no relationship between PA and most of the markers of MetS were found. Casazza[17] and colleagues reported that diet was more closely related to MetS compared to PA. Prevalence of MetS is also reported to be much lower in adolescents with higher quality diet and PA.[38] More studies should be conducted on adolescents to assess dietary patterns and the presence or absence of insulin resistance, to take it a step further.

Limitations against which the results should be interpreted include the fact that the participants are from a localised community in the North West Province and do not represent all adolescents in South Africa. Longitudinal changes in PA and the risk factors of MetS should be investigated to obtain more information with regards to cause and effect, while this study presented data of a cross-sectional nature. Finally, the study analysed PA obtained by means of questionnaires, which could lead to either over- or under-estimation of PA. Future studies should include PA data which has been objectively determined.

Conclusion

As a marker of MetS, DBP was shown to be significantly negatively associated with PA measures in adolescents from Tlokwe Municipality of the North West Province, South Africa. The lack of a consensus criterion for classification of MetS in adolescents provided conflicting findings of the chances of being classified with MetS, which influences PA intervention strategies to curb the increase in MetS in adolescents.

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CHAPTER 5

SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

5.1 Summary

This chapter presents a concise summary and a general conclusion, together with the limitations and recommendations of the study**. Chapter 1** outlines a brief introduction and detailed problem statement**.** It has been revealed that the risk factors that are associated with metabolic syndrome (MetS) start to manifest in childhood (Steinberger *et al.*, 2009:638), and if not corrected may track into adulthood (Morrison *et al.,* 2008:204). 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). Even though the data on MetS prevalence in children and adolescents is sparse, the percentage prevalence is high and more so in those who are overweight or obese (Cruz & Goran, 2004:60–61; Tailor *et al.*, 2010:210; Weiss *et al.,* 2004:2371). Prevalence of the MetS is reportedly lower in persons who achieve higher physical activity (PA) levels. This suggests that PA has a beneficial effect on the risk factors of MetS (Pan & Pratt, 2008:283). The aim of the study was twofold; firstly to determine the prevalence of MetS in adolescents according to both the International Diabetes Federation (IDF) and the National Cholesterol Education Programme Adult Trial Panel III (NCEP/ATP III) criteria. Secondly, to determine the relationship between PA levels and markers of MetS.

In **Chapter 2**, the detailed literature review is titled: "The relationship between physical activity and markers of the metabolic syndrome". It was found that high PA is associated with substantial health benefits. However, PA levels are decreasing with the end results being detrimental health outcomes and premature death later in life (Warburton *et al.*, 2006:801). Low levels of PA are associated with overweight and obesity, which increases the prevalence of MetS (Platat *et al.*, 2006:2084; Steinberger *et al.,* 2009:638; Weiss *et al.,* 2004:2370; Zeelie *et al.,* 2010a:293). As with adults, these relationships have been observed in adolescents too. Overweight is highly prevalent in South African adolescents (Rossouw *et al.,* 2012:913; Monyeki *et al.,* 2012:377). Persons from rural areas who were once immune to the burden of overweight are now also experiencing a high prevalence of risk factors for MetS (Kimani-Murage *et al.,* 2010:6).

Overweight or obesity exacerbates the presence of MetS, especially in overweight compared to normal weight groups (Friend *et al.*, 2013:73; Matsha *et al.*, 2009:363). There are different criteria for defining MetS with no single widely accepted definition (Jessup & Harrell, 2005:26; Thaman & Arora, 2013:54). Studies have used different diagnostic criteria to define MetS making it difficult to compare the prevalence across different studies (Shankar & Sundarka, 2003:275). Needless to say, the prevalence of MetS still remains high in both children and adolescents ranging from 1.9% in the normal weight group and up to 32% in the overweight group (Matsha *et al*., 2009:363; Rensburg *et al*., 2012:3; Tailor *et al*., 2010:210). There is limited data on the prevalence of MetS in South African adolescents. Of the few studies that have reported the prevalence of MetS, these were mainly conducted on participants from coastal areas of South Africa (Matsha *et al*., 2009:363; Rensburg *et al*., 2012:3).

Studies reporting the relationship between PA and markers of MetS in adolescents are also limited. Although a relationship has been reported between PA and selected markers of MetS, not all markers were included (DuBose *et al*., 2015:367; Zeelie *et al*., 2010b:154). It is, however, not clear in the literature what the relationship between PA and MetS score or prevalence is. A study by Casazza *et al*., (2009:6) reported associations between PA and some of the individual markers including HDL-C and triglycerides but did not find an association between PA and MetS. A study on Mozambique adolescents also did not find any clear association between PA and MetS (Dos Santos *et al*., 2013:19). Other studies have, however, found a clear relationship between PA and MetS, showing that high PA is associated with the low occurrence of MetS (Kelishadi, 2007:69; McMurray *et al*., 2008:5).

Due to limited studies on the prevalence of MetS in South African adolescents and how it relates to PA, it seemed fitting to achieve the objectives of this study through analysing the data collected during the Physical Activity, Health and Longitudinal Study (PAHLS). The findings from the study were therefore prepared as two separate manuscripts. In the first paper, **Chapter 3,** entitled "The prevalence of the metabolic syndrome in South African adolescents according to IDF and NCEP/ATP III criteria: the PAHL study", the prevalence of MetS in adolescents residing in the Tlokwe Municipality in Potchefstroom was determined. Furthermore, the prevalence of the MetS according to different weight categories was observed. The article has been submitted to the *Journal of Endocrinology, Metabolism and Diabetes of South Africa.* The results of the study indicated that the prevalence of MetS in adolescents is 2.3% using IDF criteria and 5.6% with NCEP/ATP III. Overweight adolescents had significantly higher prevalence of MetS compared to the normal weight group with both diagnostic criteria ($p<0.05$).

In addition, the results show that 7.9% and 22.9% (IDF and NCEP respectively) of the adolescents present with two or more risk factors of MetS.

In the second article, **Chapter 4** titled: "Relationship between physical activity levels and metabolic syndrome markers in adolescents from the North West Province: the PAHL study", only 25% of the adolescent boys and girls achieved the recommended ≥60 min MVPA per day. The majority of adolescents reported low PA levels (64.4%) compared with those that reported moderate-high PA. An inverse significant relationship between vigorous PA and diastolic blood pressure (DBP) (r =-0.14; p=0.05) was found. The odds of being diagnosed with MetS (NCEP/ATP III) when not meeting recommended PA guidelines is 2.4 times higher than when meeting the PA guidelines. These findings were not supported when the IDF criteria were applied, however, these findings were not significant with both diagnostic criteria and merely give an indication of the direction of the findings. This article has been prepared for submission to the *Journal of Physical Activity and Health*.

5.2 Conclusions

The conclusions that can be drawn from this study, based on the hypotheses set in Chapter One, will be presented:

Hypothesis 1: A high prevalence of MetS will be present in adolescents residing in the Tlokwe Municipality of the North West Province.

The results present a high prevalence of MetS in the adolescents from this study. The prevalence of MetS according to IDF criteria was 2.3%, while NCEP/ATP III criteria indicated 5.6 %. There was no significant gender difference with either criterion (p>0.05). It was further discovered that percentages are significantly higher in overweight compared to normal weight adolescents (IDF 13.3% v/s 0.8% p<0.01; NCEP/ATP III 30.0% v/s 2.3% p<0.01). MetS was absent in the underweight group. The results further reveal that 7.9% and 22.9% (IDF and NCEP respectively) of the adolescents have two or more of the risk factors of MetS. The first hypothesis is therefore ***accepted***.

Hypothesis 2: There will be a significant inverse relationship between PA levels and MetS markers of adolescents residing in the Tlokwe Municipality of the North West Province.

The results (Chapter 4, show that vigorous PA was found to be significantly inversely associated with DBP (r=-0.14; p=0.05). No significant relationship was noted between PA measures and the other markers of MetS. The odds of being diagnosed with MetS (NCEP/ATP III) when not meeting recommended PA guidelines is 2.4 times higher than when meeting PA guidelines. When MetS is diagnosed using the IDF criteria, no clear relationship between PA recommendations and MetS is indicated. These findings were, however, not significant with either diagnostic criteria. Only 25% of the adolescents included in the study met the recommended PA guidelines. The majority of the adolescents reported low PA levels (64.4%) in comparison to participants meeting moderate-vigorous PA. The second hypothesis is therefore ***partially accepted***.

In **Chapter 1**, two questions were asked: Firstly, what is the prevalence of MetS in adolescents residing in the Tlokwe Municipality of the North West Province? Secondly, what is the relationship between PA levels and the markers of MetS in adolescents in the Tlokwe Municipality of the North West Province? A high prevalence of MetS in adolescents in the Tlokwe Municipality of the North West Province was found, with a large number of adolescents having two or more risk factors. Based on the literature review, it means that these adolescents are at risk of carrying the risk factors into adulthood and developing MetS later in life if no intervention is performed. MetS in the overweight participants is significantly higher compared to the normal weight group. This finding indicates that overweight can be seen as a contributing factor to the risk of MetS. Therefore it is important to reduce overweight and obesity in order to curb the risk factors of MetS in adolescence if the risk of MetS in adulthood is to be reduced.

The different results with regard to prevalence that were found when the two widely accepted definitions of MetS were applied, points to the dilemma of diagnosing and intervening in an appropriate manner. The NCEP/ATP III criteria give a prevalence that is twice that of the IDF. The IDF criteria have high waist circumference as a prerequisite, which is not the case for NCEP/ATP III, which means that some of the adolescents with three risk factors or more were excluded merely because they have normal waist circumference. Furthermore, those not meeting PA guidelines were more likely to be diagnosed with MetS when applying the NCEP/ ATP III criteria than with the IDF criteria. Therefore, there is a need to develop standardised consensus criteria for MetS classification in adolescents. This will assist in confidently implementing intervention strategies that will neither be premature nor delayed.

Physical inactivity and overweight are among the driving forces behind an increased prevalence in high blood pressure (Ataklte *et al*., 2015:294; Muluvhu *et al*., 2014:393; Murthy *et al*., 2013:347). With MetS prevalence evidently higher in the overweight group, special attention should be given to assist in reducing overweight and promoting PA in adolescence. Promotion of vigorous PA which appears to have a significant negative association with DBP is a step in the right direction. Strategies should be put in place that will potentially increase vigorous PA levels, and this will assist in controlling DBP levels in adolescents. Vigorous PA can be used to lower the prevalence of MetS and in so doing prevent future morbidity and mortality later in life.

The overreaching conclusion of the study is therefore that adolescents aged 15 years residing in the Tlokwe Municipality of the North West Province are not adequately active as determined by the international physical activity questionnaire; this inactivity possibly contributes to the overweight that was observed and associated high prevalence of MetS. An increase in PA might reduce the risk of MetS via the mechanisms that reduce blood pressure.

5.3 Limitations and Recommendations

It is important to recognise that the findings from this study should be interpreted against the background of some limitations. The sample in the study is not statistically representative of the whole population because it was not randomly selected. The findings do, however, give an indication of the direction of movement in terms of the prevalence of MetS in South African adolescents living in the Tlokwe Municipal area. Adolescents included in the study were of the same age group, therefore the results cannot be used to generalise across all ages of adolescents. Another factor that served as a limitation is the cross-sectional nature of the study which does not allow inference of causation.

The use of only the subjective measure of PA also poses as a limiting factor. There is a poor level of agreement between subjective and objective measures of PA. Objective measures give a more precise measure of PA, however, it is advisable that both measures be used in combination in order to give more detailed and a complete picture of PA (Skender *et al.*, 2016:8).

There is a high prevalence of MetS in adolescents in the Tlokwe Municipality. In addition, the majority of the adolescents not yet diagnosed with MetS have at least one of the risk factors of the syndrome. Diet and PA intervention are recommended to lower the prevalence and prevent future morbidity and mortality due to cardiovascular diseases resulting from MetS. The current study reports an association between PA measures and DBP. The use of PA intervention as one of the tools to prevent or treat high blood pressure in adolescents is therefore recommended.

The two criteria used in the diagnosis of MetS give different percentages, selecting one set of criteria over the other could result in either over- or under-estimations of MetS. This could potentially lead to either premature intervention or delayed interventions. A recommendation made from the current study is the determination of standardised consensus criteria for the classification of MetS in South African adolescents.

5.4 Future studies

Future studies should follow a longitudinal design in order to determine the critical time in adolescence when the risk factors for MetS develop. Adolescents of all age groups should be included in new studies in order to determine at which age adolescents are more susceptible to MetS. Upcoming studies that look at the relationship between PA and MetS markers should use both objective and subjective measures of PA in order to paint a clear picture of PA in adolescence.

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APPENDIX A

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8. The submission adheres to the instructions to authors in terms of all technical aspects of the manuscript.

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APPENDIX B

Journal of physical activity and health

Author Guidelines (JPAH)
Prior to submission, please carefully read and follow the submission guidelines detailed below. Authors must submit their manuscripts through the journal's ScholarOne online submission system. To submit, click the button below:

Authorship Guidelines
The Journals Division at Human Kinetics adheres to the criteria for authorship as outlined by the International Committee of Medical Journal Editors*:

Each author should have participated sufficiently in the work to take public responsibility for the content. Authorship credit should be based only on substantial contributions to:

a. Conception and design, or analysis and interpretation of data; and
b. Drafting the article or revising it critically for important intellectual content; and
c. Final approval of the version to be published.

Conditions a, b, and c must all be met. Individuals who do not meet the above criteria may be listed in the acknowledgments section of the manuscript.
*Uniform requirements for manuscripts submitted to biomedical journals. *New England Journal of Medicine*, 1991, 324, 424–428.

Open Access
Human Kinetics is pleased to allow our authors the option of having their articles published Open Access within *JPAH*. In order for an article to be published Open Access, authors must complete and return the Request for Open Access form and provide payment for this option. To learn more and request Open Access, click here.

Manuscript Guidelines
JPAH is a peer-reviewed journal. Manuscripts reporting Original Research, Public Health Practice, Technical Notes, Brief Reports, or Reviews will be reviewed by at least two reviewers with expertise in the topical field, and the review process usually takes 6 to 8 weeks. A double-blind method is used for the review process, meaning authors and reviewers remain unknown to each other.

All types of manuscripts submitted to *JPAH* are judged on the following primary criteria: adherence to accepted scientific principles and methods, the significant or novel contribution to research or practice in the field of physical activity, clarity and conciseness of writing, and interest to the readership. There are no page charges to contributors.

Manuscripts generally should not exceed 25 pages (~5,000 words including everything *except* title and abstract pages; the word limit includes the reference section). Reviews should not exceed a total of 30 pages and Brief Reports should not exceed 15 pages. Major exceptions to these criteria must be approved through the Editorial Office before submission. Submissions should not include more than 10 tables/graphics, and should follow the

Uniform Requirements for Manuscripts Submitted to Biomedical Journals (visit ICMJE for more detail). *JPAH*welcomes and encourages the submission of supplementary materials to be included with the article. These files are placed online and can be accessed from the *JPAH* website. Supplemental material can include relevant appendices, tables, details of the methods (e.g., survey instruments), or images. Contact the Editorial Office for approval of any supplemental materials.

Standardized Publication Reporting Guides
JPAH highly recommends that authors refer to relevant published reporting guidelines for different types of research studies. Examples of reporting guidelines include:

1. Consolidated Standards of Reporting Trials (CONSORT)
2. Meta-analysis of Observational Studies in Epidemiology (MOOSE)
3. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)
4. STrengthening the Reporting of OBservational studies in Epidemiology (STROBE)
5. Improving the Quality of Web Surveys: The Checklist for Reporting Results of Internet E-Surveys (CHERRIES)

Manuscripts must be submitted in Microsoft Word® (*.doc) or rich text (*.rtf) format only. Do not submit a .pdf file. Graphics should be submitted in .tif or .jpg formats only. Before submitting, authors should complete the Manuscript Submission Checklist (see below). Authors may be asked to provide Human Kinetics with photo-ready graphics and/or a hard copy of the text. Authors are responsible for confirming the accuracy of the final copy, particularly the accuracy of references, and to retain a duplicate copy to guard against loss. Final review of the pre-published text is the responsibility of the authors. Authors of manuscripts accepted for publication must transfer copyright to Human Kinetics, as applicable.

Cover letter. Submissions must include a cover letter stating that the manuscript has not been previously published (except in abstract form), is not presently under consideration by another journal, and will not be submitted to another journal before a final editorial decision from *JPAH* is rendered. Full names, institutional affiliations, and email addresses of all authors, as well as the full mailing address, telephone number, and fax number of the corresponding author, must be provided. Authors must also provide a statement disclosing any relevant financial interests related to the research.

Manuscript Types
Original Research. A manuscript describing the methods and results of a research study (quantitative or qualitative), including the background and purpose of the study, a detailed description of the research design and methods, clear and comprehensive presentation of results, and discussion of the salient findings.

Public Health Practice. A manuscript describing the development or evaluation of a public health intervention to increase or promote physical activity in a community setting, or a study that describes translation of research to practice.

Technical Note. A short article that presents results related to a new or modified method or instrument related to physical activity measurement or an important experimental observation.

Brief Reports. A short article (15 or fewer pages), usually presenting the preliminary or novel results of an original research study or public health practice program.

Reviews. Manuscripts that succinctly review the scientific literature on a specific topic. Traditional narrative reviews are discouraged. However, well-conducted systematic reviews and meta-analyses are highly encouraged. The Editorial Office may recruit reviews on specific topics. All review articles must have approval from the Editorial Office prior to submission.

Manuscript Sections

The order of submission must be (1) Title page, (2) Abstract, (3) Text, (4) Acknowledgments, (5) Funding source, (6) References, (7) Tables, (8) Figures/Graphics.

Title page. The manuscript must include a title page that provides the full title, a brief running head, manuscript type (see definitions above), three to five key words not used in the title of the manuscript, abstract word count, manuscript word count (inclusive of all pages except the abstract and title page), and date of manuscript submission. *Do not include author names on the title page.*

Abstract. All manuscripts must have a structured abstract of no more than 200 words. Required headings are (1) Background, (2) Methods, (3) Results, and (4) Conclusions.

Text. The entire manuscript must be double-spaced, including the abstract, references, and tables. Line numbers must appear on each page in the left margin. A brief running head is to be included on the upper right corner of each page; page numbers must appear on the bottom right corner of each page.

For studies involving human subjects, the Methods section must include statements regarding institutional approval of the protocol and obtaining informed consent. For studies using animals, the Methods section must include a statement regarding institutional approval and compliance with governmental policies and regulations regarding animal welfare.

Acknowledgments. Provide the names, affiliations, and the nature of the contribution for all persons not included as an author who played a critical role in the study.

Funding source/trial registration. Details of all funding sources for the work should be provided (including agency name, grant numbers, etc.). Provide the registry name and registration number for all clinical trials (see JPAH Ethics Policies below).

Example: “This work was supported by a grant (grant #) from the National Cancer Institute, National Institutes of Health. This study is registered at www.clinicaltrials.gov (No. xxxxx).”

References. For reference lists, authors must follow the guidelines found in the *American Medical Association Manual of Style: A Guide for Authors and Editors* (10th ed.). Examples of reference style:

Journal articles: Surname of first author, initials, then surname and initials of each coauthor; title of article (capitalize only the first word and proper nouns), name of the journal (italicized and abbreviated according to style of Index Medicus), year, volume, and inclusive page numbers.

Melby CL, Osterberg K, Resch A, Davy B, Johnson S, Davy K. Effect of carbohydrate ingestion during exercise on post-exercise substrate oxidation and energy intake. *Int J Sport Nutr Exerc Metab*. 2002;12:294–309.

Book references: Author(s) as above, title of book (italicized and all major words capitalized), city and state/province of publication, publisher, and year.

Pearl AJ. *The Female Athlete*. Champaign, Ill: Human Kinetics; 1993.

Chapter in an edited book: Same as book references, but add the name of the chapter author(s) and title of chapter (capitalize first word and proper nouns) before the book information and inclusive page numbers.

Perrin DH. *The evaluation process in rehabilitation*. In: Prentice WE, ed. *Rehabilitation Techniques in Sports Medicine*. 2nd ed. St Louis, Mo: Mosby Year Book; 1994:253–276.

Tables. Each table must be accompanied by an explanatory title so that it is intelligible without specific reference to the text. Column headings and all units of measure must be labeled clearly within each table; abbreviations and acronyms must be fully explained in the table or footnotes without reference to the text.

Figures/Graphics. Graphics should be prepared with clean, crisp lines, and be camera-ready. For shading, stripe patterns or solids (black and white) are better choices than colors. Graphics created on standard computer programs will be accepted. Graphics should be submitted in .tif or .jpg formats only. Each figure and photo must be properly identified. A hard copy may be requested. If photos are used, they should be black and white, clear, and show good contrast.

Manuscript Submission Checklist
Before submitting a first or revised manuscript, the following criteria must be met:

- All sections are double-spaced
- Line numbers appear in left margin
- Page numbers appear in bottom right corner
- Brief running head appears in upper right corner
- Title page does not include author names or affiliations
- Abstract is formatted and contains fewer than 200 words
- Page count under limit for the manuscript type (15, 25, or 30 pages)
- Fewer than 10 tables/figures
- References are formatted per AMA guidelines

Submitting Author Revisions
Authors often submit their responses to reviewer comments and the modifications in the manuscript in a variety of different ways, making it quite difficult for reviewers and the Senior Associate Editors to review revisions. When submitting a revised manuscript, the author must be certain to answer all reviewer questions, comments, and concerns by including a separate response document in addition to the revised manuscript. The response document should follow the format of the Revision Template, including the reviewer comment, the author response, and the modification made to the revised manuscript (including page and line number). All modifications to the manuscript should be highlighted in yellow. Authors NOT following these guidelines when submitting their revision will have their manuscript rejected from further consideration.

Notice to Authors Wishing to Submit to JPAH
The *Journal of Physical Activity and Health* is becoming increasingly competitive. We continue to receive many more manuscripts than we can possibly publish. Therefore, in order to reduce

any delay in publishing the best science, the following guidelines should be considered prior to submitting a manuscript.

The following types of manuscripts will be given the ***lowest priority*** and are the most likely to be rejected without review:

- Small, cross-sectional, descriptive studies without any innovative features (e.g., the association between physical activity and body mass index)
- Pilot studies
- Studies having no control or reference group
- Studies in which physical activity is merely a covariable of interest
- Methodological studies with no health-related outcome (e.g., associations among three types of accelerometers)

The types of studies given the ***highest priority*** are the following:

- Etiologic or experimental studies testing a specific hypothesis or highlighting a specific mechanism relating physical activity or inactivity to health and function
- Prospective or longitudinal studies
- Evaluation studies of effective public health practice
- Studies that are truly innovative and reflect progressive thinking

JPAH Ethics Policies

The Committee on Publication Ethics (COPE), International Committee of Medical Journal Editors (ICMJE), and the Council of Science Editors (CSE) are excellent sources of information regarding misconduct in scientific publication. *JPAH* ethics policies are modeled after guidance from these three organizations.

Authorship Criteria. As noted earlier, *JPAH* adheres to the criteria for authorship as outlined by the ICMJE. Each author must provide any relevant information upon request to substantiate their contributions.

Duplicate Publication. All manuscripts must not have been published previously in any format (internet website, journal, newsletter, etc.), with the exception of abstracts presented at scientific meetings.

Trial Registration. *JPAH* complies with the ICMJE requirement regarding registration of all prospective clinical trial studies prior to subject enrollment (to learn more visit ICMJE Clinical Trials Registration). The ICMJE defines a trial as “any research study that prospectively assigns human participants or groups of humans to one or more health-related interventions to evaluate the effects on health outcomes.” Health-related interventions include behavioral treatments (e.g., physical activity).

Compliance with NIH Public Access Policy Requirements. The National Institutes of Health (NIH), as well as other research funding agencies, require open access of all publications they fund. *JPAH* and Human Kinetics, Inc., will work with authors on a case-by-case basis to be compliant with NIH Public Access Policy.

Violations of Journal Ethics Policies. Falsification of data, duplicate publication, breach of confidentiality, abuse of research subjects, and so on are considered violations of the ethical conduct of research. *JPAH* reserves the right to investigate and impart punishment for any such violation. All allegations of potential misconduct will be investigated by the *JPAH* editorial team, Human Kinetics, Inc., and possibly external experts on a case-by-case basis and final decisions will be agreed upon by the Editors in consultation with the *JPAH* Editorial Board and guided by the COPE, ICMJE, and CSE standards.

Submit a Manuscript

Articles are to be submitted electronically via ScholarOne (see submission button at the top of this page). First-time authors will create an account by following the directions on the ScholarOne page. Authors will be asked to submit a “blinded” version of their article and a separate cover sheet with names, institutional affiliations, and contact information.

Please visit ScholarOne to download *JPAH*’s copyright form, located under the "Instructions & Forms" link in the upper right corner. You do not need an account to access this information.

APPENDIX C

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

School of Biokinetics, Recreation and Sport Science
Private Bag x6001,
Potchefstroom
2520
South Africa
Tel: +27 18 299 1790
Fax: +27 18 299 1808
E-mail: andries.monyeki@nwu.ac.za
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 researcher from the School of Bio kinetics, Recreation and Sport Science are hereby making a request 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 been associated with increased mechanization, reliance on technology and urbanization, 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, osteoporosis and psychological constraints or risks of behavioural health.

Cross-sectional studies in South Africa which investigate the relationship between physical activity and determinants of cardiovascular disease for children and adults are available. Findings from these study revealed inactivity was significantly related to the determinants of cardiovascular disease. Little from the abovementioned studies could investigate physical activity and determinants of cardiovascular disease on a longitudinal basis. It is therefore important to note that South Africa is a country of paradox where obesity in children co-exists 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 disease 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 cardiovascular disease as well as delay 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 aims 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 years-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 the grade 8 learners (NB: the proportion will be as follow: in mixed schools, 35 girls and 35 boys; in blacks 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; skin folds thickness (triceps, sub scapular and calf skin folds), 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. It 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 (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 follow (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, therefore sandwiches provision will be made available upon completion of the measurements. The outcomes of this project will benefit the children and the schools with the information regarding the physical activity 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 D

School of Biokinetics, Recreation and Sport Science
Private Bag x6001,
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2520
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Fax: +27 18 299 1808
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 been 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 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 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 been associated with increased mechanization, reliance on technology and urbanization, 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, nutritional intake questionnaire as questionnaire on risk factors of life. Blood samples will be collected by a registered professional nurse who will obliged to health profession practices at all times.

The data of the study will be used for research purpose only. The measurements will not be shared with your child 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 participation in the project is very important, but it is entirely your choice. If your child choose 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 results 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 question 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 participation in this study. Should you choose that your child participate, please read and sign the attached consent form. Keep one consent form for your records and return the other copy. All received consent form 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 & 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 school. I understand that the results of this study of 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 NWP*) will be used for research purpose and nothing else. I am aware that if I have any question 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 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 provide will remain strictly confidential. I have read and understand 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)	(Date)

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

CONSENT FORM (*PAHLS*)

(Return this copy with the demographic questionnaire)

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 & 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 school. I understand that the results of this study of 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 NWP*) will be used for research purpose and nothing else. I am aware that if I have any question or concerns about the study I can contact the researcher at (018) 299 1790 /e-mail:andries.monyeki@nwu.ac.za or the PHASRec Niche Area Leader at (018) 299 1821 /e-mail:hanlie.moss@nwu.ac.za. Any questions or concerns regarding my child 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 provide will remain strictly confidential. I have read and understand 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)	(Date)

APPENDIX E

PAHLS Project - Anthropometry Proforma

Subject number:	

Name: ……………………………………………… Sport: ………………………………

Surname first names

Date of Birth:			
	Day	Month	Year

Test Date:			
	Day	Month	Year

Box height: ....

Gender: M ☐ F ☐

	ID	*Site*	*Trail 1*	*Trail 2*	*Trail 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 F

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 a 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.

1. 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?

_____ **days per week**

☐ 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 **week day**? (watching TV, Videogames/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.

Lesley Suzanne Wyldbore

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e-mail lesleywyldbore@gmail.com

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06 December 16

To Whom It May Concern

I, Lesley Suzanne Wyldbore, do herewith confirm that I have conducted an English language and grammar edit on the Master's dissertation by Caroline Madise entitled:

The relationship between physical activity and markers of the metabolic syndrome in adolescents: the PAHL study

Yours sincerely

Lesley Wyldbore
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Prof A Monyeki

ETHICS APPROVAL OF PROJECT

The North-West University Ethics Committee (NWU-EC) hereby approves your project as indicated below. This implies that the NWU-EC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title: 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)

Ethics number: NWU-0058-10-A1 (Institution / Project Number / Year / Status)

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Approval date: 2010/07/19 **Expiry date**: 2015/07/18

Special conditions of the approval (if any): None

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- *The project leader (principle investigator) must report in the prescribed format to the NWU-EC:*
  - *annually (or as otherwise requested) on the progress of the project,*
  - *without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.*
- *The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the NWU-EC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-EC and new approval received before or on the expiry date.*
- *In the interest of ethical responsibility the NWU-EC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the project;*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the project are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the NWU-EC or that information has been false or misrepresented,*
    - *the required annual report and reporting of adverse events was not done timely and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*

The Ethics Committee would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the Ethics Committee for any further enquiries or requests for assistance.

Yours sincerely

Prof MMJ Lowes
(chair NWU Ethics Committee)

APPENDIX I

PAHL STUDY

CHILD ASSENT FORM

(Applicable when participants are younger than 18 years old)

I, …………………………………………………(print full name), understand that my parent(s)/guardian(s) has given permission (said it is okay) for me to take part in the research project. I am taking part because I want to and not because I'm forced to do so. I have been assured that I can stop at any time I want to without getting into any trouble (nothing bad will happen to me and nobody will be mad at me if I want to stop). Also, I can always ask the researcher any question about the study. I am also told that the information or data collected on me will solely be used for research purpose until it is fully analysed. Additionally, I also told that the data will be shared with other collaborators for research reports.

____

Signature/Name

PAHLS VERBAL CONSENT

(Applicable when participants cannot read or write)

I ....hereby declare that I have read and explained the contents of the information sheet to the research participant. The nature and purpose of the study were explained, as well as the possible risks and benefits of the study. I am also told that the information or data collected on me will solely be used for research purpose until it is fully analysed. The research participant has clearly indicated that he/she is aware of the right to withdraw from the study at any time, for any reason and without jeopardizing his/her relationship with the research team. I hereby certify that the research participant has verbally agreed to participate in this study.

Research participant's name: ________________________________ (Please print)

Researcher's name: ________________________________ (Please print)

Researcher's signature: ______________________________

Date: ___________