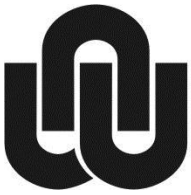




# **The relationship between resting metabolic rate and body composition in adolescents from different ethnicity: The PAHL-Study**

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20251033



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POTCHEFSTROOM CAMPUS

# **The relationship between resting metabolic rate and body composition in adolescents from different ethnicity: The PAHL-Study**

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Hons. BSc. Biokinetics

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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“If you can dream it, you can achieve it....dream big!”

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“Gardening requires lots of water - most of it in the form of perspiration”.

~Lou Erickson~

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**Disclaimer:** Any opinion, findings and conclusions or recommendations expressed in this material are those of the author(s) and therefore the NRF does not accept any liability in regard thereto.

“Without continual growth and progress, such words as improvement, achievement, and success have no meaning” ~Benjamin Franklin~

The author

2011

# Declaration



Prof. J.H. de Ridder (supervisor), Prof. S.J. Moss (co-supervisor) and Prof. M.A. Monyeki (assistant supervisor), the co-authors of the article which forms part of this dissertation, hereby give permission to the candidate, Ms V.L. Hoops to include the article as part of a Masters' dissertation. The contribution of each co-author, both supervisory and supportive, was kept within reasonable limits and included:

Me. V.L. Hoops: Developing the proposal, data collection, statistical analyses, interpretation of the results, writing of the manuscript;

Prof. J.H. de Ridder: Planning of the project, interpretation of the results, reviewing of the manuscript;

Prof. M.A. Monyeki: Principle investigator of the PAHL-study. Coordinated the study, advised on statistical analyses and interpretation thereof, structure of the manuscript, reviewing of the manuscript;

Prof. S.J. Moss: Co-investigator of PAHL-study, assisted with data collection, review of the manuscript;

thereby enabling the candidate to submit this dissertation for examination purposes. This dissertation, therefore, serves as fulfillment of the requirements for the M.Sc. degree in Biokinetics within Physical, Activity, Sport and Recreation (PhASRec) in the Faculty of Health Sciences at the North-West University, Potchefstroom Campus.

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## Abstract



Obesity in children and adolescents is on the rise and is a major risk factor for chronic disease, thus posing one of the greatest public health challenges for the 21<sup>st</sup> century. Although adolescent obesity is increasing in all ethnic groups, its prevalence is higher in non-Caucasian populations. A possible explanation for ethnic differences in the development of obesity could be ethnic differences in resting metabolic rate (RMR). A low RMR would pre-dispose an ethnic group to obesity. In South Africa limited research has been published with regards to body composition (BC) and RMR in adolescents and the possible association of RMR with BC. The first aim of this study, therefore, was to determine differences in BC and RMR between 14 year old black and Caucasian South African adolescents from the Tlokwe municipality of the North West Province, South-Africa. The second aim was to investigate whether significant relationships between the body composition characteristics body mass index (BMI), percentage body fat (%BF), fat free mass (FFM) and RMR exist in this group. The baseline data of participants in the Physical Activity and Health Longitudinal Study (PAHLS) was used. Anthropometric measurements included stature, body mass, triceps and subscapular skinfolds, and waist girth to determine BMI, %BF, FFM and waist-to-height ratio (WHTR). RMR was measured by the FitMate Pro Indirect Calorimetry (Cosmed). An independent t-test was used to compare the two groups (black *vs.* Caucasian, boys and girls respectively) with regards to body composition and RMR. Pearson correlation coefficients (adjusted for gender and ethnicity) were calculated, to study the relationship between RMR and body composition. Significant difference levels were set at  $p < 0.05$ .

The present cross-sectional results revealed significant differences in BC and RMR in black and Caucasian adolescents of the Tlokwe municipality, with Caucasian adolescents of both genders having a higher RMR and FFM compared to their counterpart black adolescents. The results further indicated that Caucasian adolescents were significantly

( $p < 0.05$ ) taller, heavier and had a higher %BF, WHTR, FFM and RMR than the black adolescents of both genders. Boys of both ethnicities had a higher RMR than the girls, with black girls having the lowest RMR. Both underweight and overweight/obesity were present in both ethnic groups and genders emphasizing the double burden of disease prevalent in South Africa. The overweight/obese group of both ethnicities had a higher FFM and RMR than the normal and underweight group. After adjusting for gender and ethnicity a high non-significant negative relationship was observed between RMR and FFM in the overweight group. The reasons for these persistent differences in ethnic groups for RMR in adolescents are not clear. A positive association between anthropometric indicators of BC and RMR influenced by gender and ethnicity was indicated. Whether the observed ethnic differences in RMR predict future weight gain and obesity awaits the results of longitudinal analyses.

It is suggested that intervention programmes be implemented focusing on the prevention of obesity in adolescents, but especially black adolescent girls, as they are indicated to be the group more prone to obesity. These results supported the literature findings and identified the need for longitudinal data regarding RMR and BC in adolescents. The PAHL-Study will continue to follow-up these adolescents over a period of time as some of the conclusions made will further be cleared, including whether the observed ethnic differences in RMR predict future weight gain and obesity.

**Keywords:** Resting metabolic rate (RMR), body composition (BC), ethnicity, adolescents, obesity

## Opsomming



Obesiteit in kinders en adolessente neem tans drasties toe, en is een van die grootste risiko faktore vir kroniese siektes - dus een van die grootste openbare gesondheids uitdagings van die 21ste eeu. Alhoewel daar 'n toename in obesiteit onder alle etniese groepe is, is die voorkoms steeds hoër onder nie-blanke populasies. 'n Moontlike verklaring vir die etniese verskil in die voorkoms van obesiteit, kan 'n etniese verskil in rustende metabolisme (RM) wees. 'n Laer RM kan moontlik lei tot 'n groter geneigtheid tot obesiteit in 'n etniese groep. In Suid-Afrika is daar egter slegs beperkte navorsing beskikbaar, aangaande liggaamssamestelling en RM in adolessente en die moontlike verband tussen liggaamsamestelling en rustende metabolisme. Die basislyndata van deelnemers van die Physical Activity and Health Longitudinal Study (PAHLS) is gebruik. Die eerste doel van die studie was om die verskil in liggaamsamestelling en rustende metabolisme van 14 jarige swart en blanke Suid-Afrikaanse adolessente, van die Tlokwe Munisipaliteit van die Noord Wes Provinsie, Suid-Afrika te bepaal. Die tweede doel was om te bepaal of daar betekenisvolle verhoudings tussen die liggaamssamestelling karakteristieke liggaamsmassa indeks (LMI), persentasie liggaamsvet (%LV), vetvrye massa (VVM) en RM bestaan in die groep. Antropometriese metings het ingesluit: lengte, liggaamsmassa, triseps en subskapulere velvoue en middelomtrek, om gevolglik LMI, %LV, VVM en middel-lengte-ratio te bepaal. RM is bepaal deur die Fitmate Pro Indirect Calorimetry (Cosmed). 'n Onafhanklike t-toets was gebruik om die twee groepe (swart vs. blank, seuns en dogters) te vergelyk in terme van liggaamsamestelling en RM. Pearson korrelasie koëffisiente (aangepas vir geslag en etnisiteit), was bereken om die verhouding tussen RM en liggaamsamestelling te bepaal.

Die huidige dwars-deursnitstudie resultate toon betekenisvolle verskille in liggaamsamestelling en RM in swart en blanke adolessente van die Tlokwe munisipaliteit- met blanke adolessente van beide geslagte wat 'n hoër RM en VVM het i.v.m. swart

adolessente. Die blanke adolessente was betekenisvol ( $p < 0.05$ ) langer en swaarder, en het 'n groter %LV, middel-lengte-ratio, VVM en RM as die swart adolessente, van beide geslagte, gehad. Seuns van beide etnisiteite, het 'n hoër RM as die meisies gehad, met swart meisies die laagste RM. Ondergewig en oorgewig/obesiteit was teenwoordig in beide etniese groepe en geslagte. Dit beklemtoon die dubbele las van siekte tans teenwoordig in Suid-Afrika. Die oorgewig/obese groep van beide etnisiteite, het 'n hoër VVM en RM as die normaal en ondergewig groep gehad. In beide die ondergewig- en normalegewig groepe het korrelasie koëffisiente, aangepas vir geslag en etnisiteit, 'n positiewe verband tussen RMR en LMI, RM en VVM getoon. Die resultate toon dat VVM, alhoewel nie betekenisvol, negatief korreleer met RMR in die oorgewig/obese adolessente. Die redes vir die volgehoue etniese verskille in RM onder adolessente is steeds nie duidelik nie. 'n Positiewe verband tussen antropometriese parameters van liggaamsamestelling en RM, beïnvloed deur geslag en etnisiteit, is aangetoon. Of die waargenome etniese verskille in RM 'n toekomstige toename in die voorkoms van obesiteit onder 'n spesifieke etniese groep voorspel, sal bevestig word deur longitudinale studies en data.

Intervensie programme, wat fokus op die voorkoming van obesiteit onder adolessente word wel voorgestel. Veral onder swart vroulike adolessente, aangesien hulle die groep is met die laagste RM en moontlik die grootste geneigdheid tot obesiteit. Hierdie resultate ondersteun vorige literatuur en identifiseer die behoefte aan longitudinale data aangaande RM en liggaamsamestelling onder Suid-Afrikaanse adolessente. Die PAHL-Studie sal hierdie adolessente monitor oor 'n periode van tyd en sommige van die aannames en gevolgtrekkings - insluitende of die waargenome etniese verskille in RM 'n geneigdheid tot obesiteit voorspel - beter verklaar.

**Sleutelwoorde:** Rustende metabolisme (RM), liggaamsamestelling, etnisiteit, adolessente, obesiteit



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# List of abbreviations



<b>A</b>	
ACSM	American College of Sports Medicine
AJPHRD	African Journal for Physical, Health Education, Recreation and Dance
ANOVA	Analysis of variances
<b>B</b>	
BC	Body composition
BF	Body fat
BMI	Body mass index
<b>C</b>	
cm	Centimetre
CVD	Cardiovascular Diseases
<b>E</b>	
EE	Energy expenditure
<b>F</b>	
FFM	Fat-free mass
FM	Fat mass
FM/m <sup>2</sup>	Fat mass/height <sup>2</sup>
<b>H</b>	
HMR	High metabolic rate
<b>I</b>	
IOTF	International Obesity Task Force
ISAK	International Society for the Advancement of Kinantropometry
<b>K</b>	
kg	Kilogram
kg.m <sup>-2</sup>	Kilogram per square metre
<b>L</b>	
LBM	Lean body mass
LLM	Lean leg mass
LMI	Liggaamsmassa indeks
LM	Lean mass
<b>M</b>	
m	Metre
mm	Millimeter
MRC	Medical Research Council of South Africa
<b>N</b>	
n	Number of data values in the sample
NRF	National Research Foundation
<b>P</b>	
PAHLS	Physical Activity and Health Longitudinal Study
PHASREC	Physical Activity, Sport and Recreation Niche Area
PHV	Peak height velocity

<b>R</b>	
RM	Rustende metabolisme
RMR	Resting metabolic rate
RQ	Respiratory quotient
<b>S</b>	
SSKF	Sum of skinfolds
Std. Dev.	Standard deviation
<b>T</b>	
TDEE	Total daily energy expenditure
TEF	Thermic effect of food
THUSA BANA	Transition and Health during Urbanisation of South Africans; BANA, children
TLM	Trunk lean mass
<b>U</b>	
US	United States
USA	United States of America
<b>V</b>	
VVM	Vetvrye massa
<b>W</b>	
WHO	World Health Organisation
WHR	Waist-to-hip-ratio
WHTR	Waist-to-height ratio
<b>Y</b>	
YRBS	National Youth Risk Behaviour Surveys
<b>Symbols</b>	
%BF	Percentage body fat
%FM	Fat mass percentage
%LM	Persentasie liggaamsvet

# Chapter 1



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## 1.1 Introduction

## 1.2 Problem statement

## 1.3 Objectives

## 1.4 Hypothesis

## 1.5 Structure of the dissertation

## References

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### 1.1 Introduction

A global increase in obesity and overweight among children and adolescents, especially African American children and girls are reported in the research literature (National Centre for Health Statistics, 2007; Steyn *et al.*, 2005:4; Mukuddem-Petersen & Kruger, 2004:842). Obesity is associated with chronic lifestyle diseases such as diabetes, hypertension and many more related risk factors (Caprio *et al.*, 2008:2212), hence related with resting metabolic rate (RMR). Several studies suggest that African-American children have a lower adjusted RMR than their Caucasian counterparts in the pre-pubertal and pubertal ages (Bandini *et al.*, 2002:1044; Yanovski, 2001:149; Kaplan *et al.*, 1996:646; Morrison *et al.*, 1996:641). A possible explanation for the differences in RMR among ethnic and gender groups could be differences in body composition (BC). Bandini *et al.* (2002:1044) stated that a reduction in energy expenditure in the pre-obese state could be a risk factor for the subsequent development of obesity.

South Africa is a country reflecting two extremes, namely obesity in children and adolescents on the one side of the spectrum (5.3% of adolescents), co-existing with



stunting and underweight (8.4% of adolescents) on the other side (Reddy *et al.*, 2010:42; Healthy Active Kids South Africa, 2007). Therefore monitoring obesity amongst different population subgroups and determining the contributing factors of obesity should be an important focus of public health research and policy makers (National Centre for Health Statistics, 2007) as early detection will enable early intervention strategies to prevent excessive body mass and fat gain before adolescence (Taeymans *et al.*, 2008:293; Nooyens *et al.*, 2007:1535). The aim of this study was to determine the body composition and resting metabolic rate (RMR) of 14 year old South African black and Caucasian adolescents in the Tlokwe municipality of the North West Province, South Africa. The second aim was to investigate whether significant relationships between the body composition characteristics BMI, %BF, FFM and RMR exist in this group.

## **1.2 Problem Statement**

Obesity in South Africa is not limited to the adult population, but commences during childhood, especially in girls (Goedecke & Jennings, 2005:546; Monyeki *et al.*, 1999:287). Obesity related risk factors and diseases formerly seen only in adults are increasingly being recognized in obese adolescents (Caprio *et al.*, 2008:2211). Although childhood obesity is increasing in all ethnic groups, its prevalence is higher in non-Caucasian populations (Caprio *et al.*, 2008:2211). Countries in economic transition from undeveloped to developed, such as South Africa are particularly affected and have an increased rate of obesity across all economic levels and age groups (International Association for the Study of Obesity, 2004). About 110 million children worldwide are classified as overweight or obese (Caprio *et al.*, 2008:2212).

According to Healthy Active Kids South Africa (2007) and THUSA BANA (Transition and Health during Urbanisation of South Africans; BANA, children) study children and adolescents from urban settings were more at risk of obesity, whereas those from rural areas were more prone to stunting (Kruger *et al.*, 2004:355). In a combined sample of children under the age of nine, 17% were obese and in 19% stunted (Healthy Active Kids South Africa, 2007). The risk of developing obesity in stunted children was also twice as high compared to those within normal body mass index (BMI)-ranges (Healthy Active Kids South Africa, 2007; Kruger *et al.*, 2004:355). The Second South African National Youth Risk Behaviour Survey 2008 (YRBS) indicated that nationally, 19.7% of

adolescents were overweight, with significantly more girls (27.8%) than boys (11.2%) being overweight. More than 60% of obese children will be obese at adulthood, which reduces the age at which non-communicable diseases become apparent (WHO, 2007).

The differences in prevalence of childhood obesity among ethnic groups may be explained among other factors by genetics, physiology, culture, socio-economic status and the environment (Goedecke & Jennings, 2005:546). Obesity develops as an interaction between a genetic predisposition and certain environmental factors, such as high-fat diets and low habitual activity energy expenditure (EE) caused by low physical activity. Obesity results from a chronic imbalance between energy intake and expenditure (WHO, 2007). Resting metabolic rate (RMR) is the major determinant of total energy expenditure (Morrison *et al.*, 1996:640) and is mainly determined by body size and body composition. Research findings show that a low habitual energy expenditure is an important risk factor for weight gain and obesity (Wurmser *et al.*, 1998:797; Kaplan *et al.*, 1996:646). A low relative RMR, expressed in relation to fat-free mass (FFM), has been found to be a risk factor for subsequent weight gain (Tremblay, 2010:130). DeLany *et al.* (2006:867) identified several variables of energy metabolism that predicted change in percentage body fat in a longitudinal study of energy metabolism in children during the pubertal growth spurt which included resting metabolic rate (RMR).

Recent evidence suggests ethnic differences related to trunk lean body mass (and the high metabolic activity of visceral organs included in the trunk lean body mass) could account for differences in RMR in adult African American and Caucasian woman but this, however, has not been studied in children and adolescents (Tershakovec *et al.*, 2002:867). DeLany *et al.* (2004:268) observed ethnic and gender differences in children where Caucasian children had a higher RMR, than African American children after accounting for differences in body composition. DeLany *et al.* (2004:273) reported that ethnic differences in RMR were more apparent in boys than in girls. Boys have a higher RMR than girls, even after adjustment for differences in body weight (DeLany *et al.*, 2004:273; Sun *et al.*, 2001:308). According to Morrison *et al.* (1996:640) the ethnic differences in RMR in girls are most pronounced in pubertal stage. Tershakovec *et al.* (2002:867) suggests that the low RMR in African American children and adolescents could be a predisposing factor for long-term weight gain and obesity, but there is limited data

available. If further investigations confirm a lower RMR in African American than in Caucasian children during pubertal development, the lower metabolism could be related to the increased prevalence of obesity in the African American population (Sun *et al.*, 2001:314).

The increasing prevalence of child and adolescent obesity, combined with the above mentioned, warrants the need to detect children and adolescents at risk for overweight or high relative fat mass as early as possible. In South Africa despite the existence of both obesity and underweight in children (Reddy *et al.*, 2010:42; Monyeki, 2006:116), limited research has been published with regards to body composition and RMR in adolescents living in the Tlokwe municipality of the North West Province. Considering the above mentioned and a scarcity of South African data available for adolescents of different ethnicities, the following research questions arise. Firstly, are there ethnic and gender differences regarding body composition (BC) and RMR in black and Caucasian adolescents, specifically from the Tlokwe municipality? Secondly, is there a significant relationship between anthropometric indicators of BC and RMR?

The purpose of this study, therefore, is to present the initial cross-sectional data on the body composition and RMR status of adolescents attending high schools in the Tlokwe municipality, as well as to add scientific knowledge to the relationship between anthropometric indicators of body composition and resting metabolic rate in South African adolescents of the Tlokwe municipality of the North West Province.

### **1.3 Objectives**

The objectives of this study are to determine:

- the difference in body composition and RMR between 14 year old black and Caucasian adolescents in the Tlokwe municipality of the North West Province, South-Africa
- the relationship between body composition characteristics Body Mass Index (BMI), fat-free mass (FFM), percentage body fat (%BF) and RMR in 14 year old black and Caucasian adolescents in the Tlokwe municipality of the North West Province, South Africa.

## 1.4 Hypothesis

The study is based on the following hypotheses:

- ethnic differences in BC and RMR exist, with Caucasian adolescents having a higher FFM and RMR than the black 14 year old adolescents of the North West Province, South Africa; and
- a positive relationship is present between body composition characteristics Body Mass Index (BMI), fat-free mass (FFM), percentage body fat (%BF) and RMR related to obesity in adolescents of the North West Province, in South Africa.

These hypotheses will be tested by measuring the RMR and body composition of 14 year old black and Caucasian adolescents in the North West Province from the Tlokwe municipality.

## 1.5 Structure of the dissertation

The dissertation is presented in four main chapters (Figure 1), namely an introductory chapter (Chapter 1), a literature review (Chapter 2), and a research article (Chapter 3) followed by a summary with conclusions, limitations and recommendations (Chapter 4). Chapter 1 includes the introduction, problem statement, objectives and hypothesis of the study, as well as a visual representation of the structure of the dissertation. The literature review (Chapter 2) with the title: “Resting metabolic rate (RMR) and body composition (BC) among adolescents of different ethnicities” contains the relevant literature available on obesity, resting metabolic rate (RMR) and body composition (BC) among adolescents of different ethnicities. Chapter 3 is presented in the form of a research article entitled “Body composition and resting metabolism rates of black and Caucasian South African adolescents: the PAHL-Study”. Chapter 3 will, therefore, present the empirical findings of measurements performed in adolescents with regards to BC and RMR. Chapter 4 concludes the study with a summary of the findings, conclusions that can be drawn from this investigation and limitations with recommendations for future research. A list of appendices will be included. Each chapter will include its relevant references. Chapters 1, 2 and 4 will be according to the Harvard referencing style of the Potchefstroom Campus of the North-West University. In Chapter 3 referencing followed the specifications of the African Journal for Physical, Health Education, Recreation and Dance (AJPHERD).



**Figure 1: Structure of Dissertation**

**References**

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## Chapter 2



### **Resting metabolic rate and body composition among adolescents of different ethnicity**

#### **2.1 Introduction**

Obesity is not limited to the adult population, but commences during childhood, especially in woman and African Americans (Goedecke & Jennings, 2005:546). Previous research studies revealed an increasing trend of overweight and obesity among children and adolescents world-wide (National Centre for Health Statistics, 2007; Steyn *et al.*, 2005:4; Mukuddem-Petersen & Kruger, 2004:842). The Report Card on the Physical Activity, Nutrition and Tobacco use for South African Children and Youth (2007) reported that more than 30% of adolescent girls and 10% of boys are obese (Healthy Active Kids South Africa, 2007). In agreement The First South African National Youth Risk Behaviour Survey of 13-19 year old schoolchildren, indicated that 17% were overweight and 4% obese (Healthy Active Kids South Arica, 2007). The Second South African National Youth Risk Behaviour Survey 2008 (YRBS) indicated that nationally, 19.7% of adolescents were overweight, with significantly more girls (27.8%) than boys (11.2%) being overweight (Reddy *et al.*, 2010:42). According to the WHO (2007), more than 60% of obese children tend to stay obese during adulthood, which reduces the age at which non-communicable diseases become apparent. The above mentioned emphasizes the need to identify predictors of weight gain in childhood to aid in prevention of childhood and adult obesity and the associated diseases (DeLany *et al.*, 2006:862).

It has been indicated that African Americans may have a lower resting metabolic rate (RMR) than Caucasians, but there is limited data for obese children and adolescents

regarding RMR (Jones *et al.*, 2004:780; Tershakovec *et al.*, 2002:867). Some investigators suggest that the relatively low RMR in African Americans could be a predisposing factor for long-term weight gain and obesity (Tershakovec *et al.*, 2002:867). Tershakovec *et al.* (2002:867) suggested that ethnic differences related to trunk lean body mass (and the high metabolic activity of visceral organs included in the trunk lean body mass) account for differences in RMR in adult African American and Caucasian woman, but this, however, has not been studied in children and adolescents. The purpose of this chapter is to review the current literature on the resting metabolic rate (RMR) and body composition (BC) among adolescents of different ethnicities and related terms.

### **2.2 Obesity**

Obesity is defined as an abnormal or excessive fat accumulation that may impair health (WHO, 2011; Himes 2010:30). Himes (2010:30) states that there is currently not agreement on firm criteria for defining exactly what constitutes obesity and excess body fat in children based on health risks. Obesity is meant to be a status related to health risks and the main concern is not the excess fat, but rather the current and subsequent health-related consequences of the excess fat (Himes 2010:30). The World Health Organisation (WHO) define 'obesity' as a body mass index (BMI) value equal to or greater than 30 kg.m<sup>2</sup> (WHO, 2011; Cole *et al.*, 2000:1240). The WHO further states that measuring obesity in children aged 5 to 14 years is challenging, because of the lack of a standard definition regarding childhood obesity worldwide. BMI is one of the most common anthropometric indices to predict relative overweight, but during periods of growth in children and adolescents when height is continually changing the appropriateness of the index has been of questionable value (Hall & Cole, 2006:283). The International Obesity Task Force (IOTF) established international cut-off points using BMI percentiles for children and adolescents to classify them accordingly as indicated by Table 2.1 (Ribeiro, 2000; Cole *et al.*, 2000:1241).

**Table 2.1 The IOTF international cut-off points that will be used (Ribeiro, 2000; Cole *et al.*, 2000:1241)**

Underweight	BMI for age < 5 <sup>th</sup> percentile
Normal weight	BMI for age between 5 <sup>th</sup> percentile and 90 percentile.
At risk of overweight	BMI for age between 90 <sup>th</sup> percentile and 97 <sup>th</sup> percentile.
Overweight	BMI for age > 97 <sup>th</sup> percentile.

**Table 2.2 Classification according to Cole *et al.* (2007) for BMI:**

Classification of Body composition	BMI (body-mass-index) kg.m <sup>2</sup>
Thinness Grade 1	17 – 18,5
Thinness Grade 2	16 - <17
Thinness Grade 3	<16
Normal weight	18.5 - <25
Overweight	25 - <30
Obesity	>30

Cole *et al.* (2007:197) proposed a BMI of 17 at age 18 as a suitable cut-off to use as the basis for an international definition of thinness in children and adolescents, as it unifies the two WHO definitions of thinness, for adults and adolescents, while extending its use to children too (Table 2.2). In addition to the primary cut off of 17, two secondary cut-offs will be used to define thinness in children and adolescents: 18.5 for grade 1 thinness and 16 used for grade 3 thinness (Cole *et al.*, 2007:197). The three cut-offs as seen in Table 2.2 correspond to the WHO graded definition of thinness. The new definitions should

encourage direct comparison of trends in child and adolescent thinness worldwide (Cole *et al.*, 2007:197).

The definition of excess body fat is vague even if total body fat mass or body fat mass percentage (%FM) is known (Himes 2010:30; Rodríguez *et al.*, 2004:S56). Rodríguez *et al.* (2004:S57) reported that in adolescents there is no consensus about %FM cut-offs for obesity. During adolescence the level of adiposity may vary widely pertaining to age, gender and pubertal development. The most consistent %FM values for the definition of excess body fat, in the absence of clear cut-off points, in female adolescents range between 30 and 35% (Taylor *et al.*, 2003:765; Taylor *et al.*, 2002:1416). In contrast to females, adiposity in male adolescents decreases with age and sexual development (Taylor *et al.*, 2002:1416). Therefore, %FM cut-offs selected for excess body fat in males are 25–30% for adolescents aged 10–15 years (Taylor *et al.*, 2003:765; Taylor *et al.*, 2002:1416). According to Delany *et al.* (2006:864), children having a body fat percentage greater than 25% are classified as obese.

The occurrence of obesity at present is unparalleled in the history of mankind. Obesity in children and adolescents is on the rise and is found to be a major contributing risk factor for chronic disease, thus posing one of the greatest public health challenges for the 21<sup>st</sup> century (Caprio *et al.*, 2008:2212; WHO, 2007). The prevalence of obesity among children and adolescents across all race, socio-economic and gender groups has more than tripled for US children over the past three decades (WHO, 2011; Caprio *et al.*, 2008:2212; National Centre for Health Statistics, 2007). The National Centre for Health Statistics (2007) recognizes the high prevalence of obesity and rapidly increasing trend of childhood and adolescent obesity as a major public health problem. Obesity related risk factors and diseases formerly seen only in adults are increasingly being recognized in obese adolescents (Caprio *et al.*, 2008:2211). Worldwide people of all ethnicities in first and third world countries are affected by this problem as a result of economic, social and cultural changes (Mukuddem-Petersen & Kruger, 2004:842). Although childhood obesity is increasing in all ethnic groups, its prevalence is higher in non-White populations (Caprio *et al.*, 2008:2211). Possible reasons for the differences in prevalence of childhood obesity among ethnic groups include genetics, physiology, culture, socio-economic status and the environment (Goedecke & Jennings, 2005:546). Countries in economic transition

from undeveloped to developed, such as South Africa are particularly affected and have an increased rate of obesity across all economic levels and age groups (International Association for the study of obesity, 2004). Once considered a problem only in high income countries, obesity is now dramatically on the rise in low and middle-income countries, particularly in urban settings. Close to 35 million overweight children are living in developing countries and 8 million in developed countries (WHO, 2011). Overweight and obesity are linked to more deaths worldwide than underweight, as 65% of the world's population lives in countries where overweight and obesity kill more people than underweight (including high-income and most middle-income countries) (WHO, 2011). About 110 million children worldwide are classified as overweight or obese (Caprio *et al.*, 2008:2212). Even in developing countries, where under nutrition has conventionally been the major health concern, overweight and obesity are becoming more prevalent (Caprio *et al.*, 2008:2212). It is estimated that if obesity continues to increase at the same rate as in the 1990's, a projected 15 million children and adolescents in the European Region will be obese by 2010 (WHO, 2007).

During 1963-1970 the prevalence of obesity was lower in African American children than in Caucasian children, but Tershakovec *et al.* (2002:867) found similar or higher rates of obesity among African American children. This rapid increase in the prevalence of childhood obesity among African American children and the higher rates of obesity in African American adults states the importance of identifying factors related to these trends and ethnic differences.

### 2.2.1. Causes of obesity

Obesity is a complex medical condition, affected by various contributing factors including urbanisation, socio-economic, genetic, hereditary, physiological, environmental and behavioural characteristics (WHO, 2011; Caprio *et al.*, 2008:2211; Goedecke & Jennings, 2005:546). In essence, however, the cause of obesity is an energy imbalance between calories consumed and calories expended (WHO, 2011). Consequently if there is an increase in energy intake and a decrease in energy expenditure the positive energy balance results in obesity as the consequence. Global increases in obesity are attributable to various intertwining factors namely:

- Globalisation and Urbanisation: Globalisation increases the risk amongst urban population by creating an environment that promotes large consumption of food high in sugar and fat. Rapid and unplanned urbanisation accelerates changes in traditional diets and physical inactivity leading to weight increases (WHO, 2011; Vorster *et al.*, 2000:506). The result of urbanisation is that South African children are not playing traditional games as often as before, due to high crime rates in urban areas and fear of playing outside (Vorster *et al.*, 2000:506).
- Socio-economic factors include poverty, violence, lack of education and inadequate services contributing to increasing obesity amongst children (Vorster *et al.*, 2000:506).
- Lack of physical activity: the absence of physical activity education in many South African schools is an important contributing factor to obesity in schoolchildren (WHO, 2011; Vorster *et al.*, 2000:506).
- A sedentary lifestyle is promoted by the advancement in technology including television viewing, play stations and computer games, contributing to obesity amongst children as a result of a lack of physical activity (Reddy *et al.*, 2010:43; Kruger *et al.*, 2004:352).

### 2.2.2. Consequences of obesity

The health consequences of childhood obesity are less clear than those of adults, but research has shown that childhood obesity is strongly associated with risk factors for cardiovascular disease, diabetes, orthopedic problems and mental disorders (WHO, 2011; Caprio *et al.*, 2008:2212; Dietz, 1998:519). Immediate consequences of obesity in childhood are psychosocial and cardiovascular risk factors such as high cholesterol levels, hypertension and abnormal glucose tolerance (Ogden *et al.*, 2002:1728). Additionally childhood obesity is associated with obstructive sleep apnea, fatty liver, asthma, ovarian hyperandrogenism, orthopedic problems and chronic kidney disease (Caprio *et al.*, 2008:2212). The WHO (2011) stated that childhood obesity is associated with a higher chance of obesity, premature death and disability in adulthood. In addition to increased future risks, obese children experience breathing difficulties, increased risk of fractures, hypertension, early markers of cardiovascular disease, insulin resistance and psychological

effects (WHO, 2011). More than 60% of obese children will be obese in adulthood, which reduces the age at which non-communicable diseases become apparent (WHO, 2007). The Bogalusa Heart Study found that obese African American children were even more likely to remain obese as adults (83%) than obese Caucasian children (68%) (Freedman *et al.*, 1997:424).

Obesity during childhood, therefore, correlates with adult obesity and increased risk for chronic diseases such as:

- Cardiovascular diseases (CVD) – mainly heart disease and stroke.
- Hypertension.
- Type 2 diabetes mellitus.
- Musculoskeletal disorders (especially osteoarthritis).
- Some cancers (breast, colon and endometrial)
- A higher risk for premature death and disability in adulthood (Caprio *et al.*, 2008:2212; WHO, 2007; Rush *et al.*, 2003:1133; Williams, 2001:158).

The above mentioned, combined with the increasing prevalence of childhood and adolescent obesity is reason enough to detect children and adolescents at risk for overweight or high relative fat mass as early as possible and to start with interventions to prevent excessive body mass and fat gain before adolescence (Taeymans *et al.*, 2008:293; Nooyens *et al.*, 2007:1535).

### 2.2.3 Prevalence of obesity among South African adolescents

South Africa is a country reflecting two extremes, namely obesity in children and adolescents on the one side of the spectrum, co-existing with stunting and early nutritional deprivation on the other side (Reddy *et al.*, 2010:42; Healthy Active Kids South Africa, 2007). In a combined sample of children under the age of nine, 17% were obese and in 19% stunted (Healthy Active Kids South Africa, 2007). According to Healthy Active Kids South Africa (2007) and the THUSA BANA (Transition and Health during Urbanisation



of South Africans; BANA, children) study, children and adolescents from urban settings were more at risk of obesity, whereas those from rural areas were more prone to stunting, also that the risk of developing obesity in stunted children was twice as high compared to those within normal BMI-ranges (Healthy Active Kids South Africa, 2007; Kruger *et al.*, 2004:355). The National Household Food Consumption Survey reported that 17.1% of urban children in South-Africa (1-9 yrs), were overweight or obese (Goedecke & Jennings, 2005:546).

The Physical Activity, Nutrition and Tobacco use for South African Children and Youth (2007) reported that more than 30% of adolescent girls and 10% of boys were obese (Healthy Active Kids South Africa, 2007). The Second South African National Youth Risk Behaviour Survey 2008 indicated that nationally, 19.7% of adolescents were overweight, with significantly more girls (27.8%) than boys (11.2%) being overweight (Reddy *et al.*, 2010:38). When ethnicity and gender were taken into account, significantly more black girls (28.9%) were overweight when compared to black boys (9.5%) (Reddy *et al.*, 2010:38). With regards to obesity, the national prevalence of obesity was 5.3%, with significantly more girls (7.2%) being classified as obese than boys (Reddy *et al.*, 2010:38). Significantly more black girls (7.3%) than black boys (2.6%) were obese (Reddy *et al.*, 2010:38).

The THUSA BANA study found that 7.8% of all the children and adolescents were either overweight or obese (Kruger *et al.*, 2004:354). Twice as many girls were overweight/obese (10.0%) than boys (5.6%). White children (14.2%) had the highest prevalence of overweight/obesity compared to 7.1% of black children being overweight/obese (Kruger *et al.*, 2004:354). Regarding gender the overweight/obese prevalence rate was twice as high in girls (10%) than in boys (5.6%). Morrison *et al.* (1996:638) state that factors linked to the development of obesity and the ethnic difference in obesity for girls during adolescence could include differences in RMR, calorie intake and activity energy expenditure. Therefore, monitoring obesity amongst different population subgroups and determining the contributing factors of obesity is an important focus of public health research (National Centre for Health Statistic, 2007; Kruger *et al.*, 2004:357).

## 2.3 Body composition

### 2.3.1. Anthropometric measurements of body composition

Health professionals commonly use anthropometric measurements such as BMI, waist-to-height ratio (WHTR), body-fat percentage, circumference measurements and other health indicators to calculate body composition and classify individuals with illness or disease (ACSM, 2010:58; Hills & Kagawa, 2007:39; Stinson, 1992:124). Anthropometry is one of the most basic tools to assess nutritional status, whether over-nutrition or under-nutrition (Wang *et al.*, 2002:971). The accurate assessment of body composition in children and adolescents is complicated and challenging due to growth and maturation factors (Hills & Kagawa, 2007:38). Body composition assessment methods at best provide estimations or predictions (Hills & Kagawa, 2007:38). Anthropometry is the preferred approach, as it is non-invasive, inexpensive and an easy to use field method (Hills & Kagawa, 2007:38; Heyward & Wagner, 2004:90).

BMI for age and gender is widely accepted as the most appropriate and useful measurement for defining overweight and obesity in children and adolescents, as it is easy to determine and correlates well with body fat (WHO, 2011; Cole *et al.*, 2000:1241). Mei *et al.* (2002:984) provide additional support for the use of BMI-for-age and weight-to-height in assessing underweight and overweight in adolescents as an indicator of body fatness. In disagreement Yan *et al.* (2007:751) state that in practice of prevention, control and intervention for childhood obesity, BMI has limitations. Firstly, it fails to assess the accumulation of abdominal fat, which mainly increases risk for associated diseases. Secondly, BMI cut-off points for age and gender differ for different ethnic populations and can not be applied or used to compare children from different ethnicities (Yan *et al.*, 2007:751; Hills & Kagawa, 2007:39). Thirdly, as stated by Wang (2004: S21), BMI does not distinguish between measures of bone mass, fat free mass and fat mass and as such, differences in bone density, muscle and adipose tissue makes it difficult to describe obesity in all age-sex-race groups optimally. BMI, therefore, has a great measure of considerable variability in body composition for any given value, because as stated above it does not take into account the individual's body composition (Ode *et al.*, 2007:403). As such, the BMI is often used to determine overweight and obesity, usually by comparison

of individuals to age- and sex-specific percentiles from a reference population (Wang, 2004:S22).

WHTR is a simple and accurate index for identifying obesity in children and adolescents (Yan *et al.*, 2007:751). It is also more accurate to identify obese children as it combines the advantages of BMI and waist-to-hip ratio, and gives an indication of abdominal adiposity which is associated with various chronic diseases (Yan *et al.*, 2007:751). According to Yan *et al.* (2007:751), WHTR has a higher accuracy than waist circumference in identifying obese children as defined by BMI. It is suggested that cut-off points for WHTR should be 0.475 for boys and 0.485 for girls to ensure the highest sensitivity and specificity (Yan *et al.*, 2007:752).

Traditionally, percentage body fat has been estimated from measuring skinfold thickness, which correlated well with body fatness. The skinfold method is an indirect measuring method of the thickness of subcutaneous adipose tissue (De Ridder, 2002:23). Different sites on the body are measured with a caliper by grasping the subcutaneous adipose tissue beneath the skin (De Ridder, 2002:23). Rodríguez *et al.* (2004:S57) stated that the equations of Slaughter *et al.* (1988) have been reported to be superior to other skinfold-based equations to assess body fat percentage (BF%) in the adolescent population (Moreno *et al.*, 2006:195). The use of skinfold thickness, however, has been questioned as skinfold thicknesses are poorly reproducible and only a few regional body sites are measured (Moreno *et al.*, 2006:195; De Ridder, 2002:23; Stinson, 1992:124). Marfell-Jones *et al.* (2006:63) declared that skinfolds have the poorest accuracy and precision of all surface anthropometry measurements and great care is needed to ensure accurate and reproducible measurements. As such selecting the single best or most accurate measure of obesity is difficult as a result of the lack of consistent references for measuring adolescent obesity (Wang *et al.*, 2002:971).

### 2.3.2. The role of body composition for total health and well-being.

Determining fat and fat-free mass is of considerable interest in the evaluation of nutritional status (Wang *et al.*, 2002:971). Over and under-nutrition contribute to increased mortality and morbidity. The burden of nutritional problems is shifting from energy imbalance

deficiency to excess among children and adolescents, and few studies have addressed the issue concerning obesity in older children and adolescents worldwide (Kruger *et al.*, 2004:357; Wang *et al.*, 2002:971; Monyeki *et al.*, 1999:287). The assessment of body composition is useful for the screening of excess body fat and its related metabolic complications (Rodríguez *et al.*, 2004:S54).

Excess body fat is associated with adverse metabolic complications and, therefore, obesity is more than an excessive fat deposition (Rodríguez *et al.*, 2004:S54). In adolescents, excess body fat and specifically increased intra-abdominal visceral fat are related to dyslipidemia, hypertension, impaired glucose tolerance and insulin resistance (Rodríguez *et al.*, 2004:S57). This cluster of metabolic abnormalities already appears in obese adolescents and increases the risk of cardiovascular diseases (Moreno *et al.*, 2006:195). Therefore, Rodríguez *et al.* (2004:S57) found that waist circumference seems to be the best anthropometric predictor for the screening of metabolic syndrome in adolescents.

### 2.3.3. Gender differences and body composition

Vizmanos and Marti-Henneberg (2000:204) described adolescence as a global acceleration of growth and maturation, with differential changes between both genders. The onset of puberty begins earlier in girls than in boys, but both experience weight gain, a yearly height velocity and increase in fat-free mass and bone mineral content (Vizmanos & Marti-Henneberg, 2000:204). This period of development usually begins between the ages of 9-13 years in girls and 10-14 years in boys (Bitar *et al.*, 1999:1209). Both genders show significant body weight increases with peak weight velocity in girls occurring approximately 6-9 months later than peak height velocity (Hills & Kagawa, 2007:37.) Differences in body composition as a result of maturation become apparent as girls gain more adipose tissue than boys, whereas boys gain more lean tissue, especially skeletal muscle (Hills & Kagawa, 2007:37; Bandini *et al.*, 2004:1262). The preferential deposition of body fat in girls and skeletal muscle in boys are the defining body composition changes during the adolescent years (Hills & Kagawa, 2007:37). Bitar *et al.* (1999:1214) found that post pubertal boys had a higher FFM than pubertal boys, with the same fat mass (FM). In

girls the increase in FFM and FM resulted in great differences in body composition between post pubertal boys and girls (Bitar *et al.*, 1999:1214).

Adolescent girls have a higher amount of fat mass than boys and an increase in body fat during pubertal development independent of chronological age (Rodríguez *et al.*, 2004:S55; Vizmanos & Marti-Henneberg, 2000:204). In contrast adolescent boys experience a decrease in body fat, higher peaks of height velocity and an increase in both shoulder span and leg-to-trunk length ration (Vizmanos & Marti-Henneberg, 2000:204). Rodríguez *et al.* (2004:S55) stated that gender differences in fat mass are apparent long before puberty. Rodríguez *et al.* (2004:S55) mentioned that the ration of body fat and its distribution pattern may be more related to gender and pubertal development stage than to age.

According to Siervogel *et al.* (2003:36), there is a sudden increase in total body fat during puberty, although the increase in proportion body fat is slower in boys than in girls, as a result of a simultaneous increase in fat-free mass. Fat tissue accumulates at a rate of 1.14 kg/year in girls, in contrast to boys where there is a decrease in fat tissue at a rate of 1.15kg/year (Rogol *et al.*, 2002:196). Ruhl *et al.* (2004:576-577) found that woman have a higher total percentage of body fat than men. Sun *et al.* (2001:312) found that there is an increase in lean mass (LM) in boys and girls with an increase in age and maturation. Boys have a later growth spurt but a longer increase in LM than girls resulting in boys having a larger LM. DeLany *et al.* (2004:269) found several sex differences regarding body composition: firstly boys were heavier, secondly they had a higher body mass index ( $\text{kg}\cdot\text{m}^{-2}$ ) and lastly boys had more fat-free mass (FFM) than girls.

#### 2.3.4. Age, maturation and body composition

Adolescence is a critical period in which important body composition changes occur. During pubertal development there is an increase of total body mass and its relative distribution which is gender related (Hills & Kagawa, 2007:37; Rodríguez *et al.*, 2004:S57). Puberty is identified as a period of maturation of secondary sexual characteristics and drastic changes in body composition, energy partitioning and hormone concentration (Sun *et al.*, 2001:308). Energy metabolism changes as a result of dynamic

changes in body composition during pubertal maturation (Bitar *et al.*, 1999:1209). Marked changes in physical size, shape and body composition occur during puberty. In girls, the peak weight velocity occurs approximately 6-9 months later than the peak height velocity. In boys, both peak height and weight velocity occur at approximately the same time (Hills & Kagawa, 2007:38).

Buyken *et al.* (2009:221) found that prepubertal body composition in healthy girls and boys is not critical for the initiation of the pubertal growth spurt, but affects the progression of pubertal development resulting in earlier attainment of later pubertal stages. The above mentioned longitudinal study in healthy girls and boys showed that body composition 1 or 2 years before the onset of the pubertal growth spurt is not critical for the onset of puberty. In contrast prepubertal body composition influenced how quickly girls and boys progressed through puberty and is thus related to puberty duration and the age at which later pubertal characteristics occur, rather than to the time at which puberty is initiated (Buyken *et al.*, 2009:223-224). Buyken *et al.* (2009:224) further indicated that children with a higher prepubertal BMI or higher fat mass/height<sup>2</sup> (FM/m<sup>2</sup>) proceeded more rapidly to peak height velocity (PHV) or menarche.

Guo *et al.* (1998:581) found that children with a higher maturation rate had a higher accumulation of both FM and LM, than children who had a lower maturation rate. African American children begin puberty earlier than Caucasian children. The influence of maturation on body composition and RMR is more apparent at a younger age in African Americans and as such they have a higher LM than Caucasian children at a certain age (Morrison *et al.*, 1996:639).

### 2.3.5. Ethnic differences in body composition

Body composition differs significantly between African Americans and Caucasians (Gallagher *et al.*, 2005:906; Torriani & Grinspoon, 2005:731; Gasperino, 1996:337). Gasperino (1996:345) found that African American woman have 5-20% more bone mass and 5-10% more muscle mass than Caucasian woman of the same age. Gallagher *et al.* (2005:906) reported that African Americans have less visceral fat than Caucasians, but that fat distribution only significantly differs at high levels of fat deposition. According to

Gallagher *et al.* (2005:906) and Tomani and Grinspoon (2005:731), African Americans have a higher intramuscular fat distribution and African American woman reach a higher peak bone mass than Caucasian woman.

According to Hunter *et al.* (2000:502) and Sun *et al.* (2001:310), African Americans have less trunk lean mass (TLM), more limb lean mass and a lower RMR compared to Caucasians. African American children have less visceral and hepatic fat than Caucasian children. Sun *et al.* (2001:310) established that African American children have a higher lean leg mass (LLM) and lower TLM compared to Caucasians. LLM is the main component of total lean mass and the sum of skeletal muscle in the arms and legs (Sun *et al.*, 2001:310). TLM contributes more to RMR than LLM due to highly metabolic organ mass (Sun *et al.*, 2001:310). African American children have longer extremities, shorter trunk dimensions and a higher density of FFM (due to an increased bone mineral content and bone mineral density) (Sun *et al.*, 2001:310). Caprio *et al.* (2008:2214) suggested that another possibility could be fundamental metabolic differences by ethnicity. Ethnic differences in RMR may partly be due to differences in FFM or organ mass.

Ethnic differences in body fat distribution (central obesity) influence the morbidity pattern and health risks associated with obesity (Caprio *et al.*, 2008:2214). Central obesity (fat in the abdominal area) is associated with an increased risk of insulin resistance, diabetes, dyslipidemia, atherosclerosis and hypertension (Goedecke & Jennings, 2005:549). The 2002 South African Demographic and Health Survey (Puoane *et al.*, 2002:1038) indicated that 42% of women, mostly black, and 9.2% of men, mostly Caucasian, had central obesity. Black and Indian populations have a higher prevalence of developing type 2 diabetes compared to Caucasians, whereas coronary heart disease is more common under Caucasian populations (Goedecke & Jennings, 2005:550). It is clear that South Africans of all ethnicities are affected by obesity and the associated diseases. This is confirmed by a study done by Senekal *et al.* (2003:109) among 554 economically active South African adults, where more than half of Caucasian men studied (56.4%) were obese or overweight and 42.2% of Caucasian women were classified as obese or overweight. High percentages of black men (49.3%) and women (74.6%) were obese (Senekal *et al.*, 2003: 109).

## 2.4 Resting metabolic rate

Resting metabolic rate is the collective ongoing biological processes involved in cellular and tissue maintenance and repair, and is the largest fraction of energy spent by humans over time (Wang *et al.*, 2001:331). Total daily energy expenditure is comprised of resting energy expenditure (comprising 60-80%), energy required for physical activity and growth (30%) and digestion of food (10%) (Morrison *et al.*, 1996:640) as visually presented by Figure 2.1. Resting metabolic rate (RMR) is a physiological variable that provides an estimate of the minimal energy cost of living. RMR is expressed as 1kcal/min in healthy people and represents the main component of daily energy expenditure (Tremblay, 2010:130).

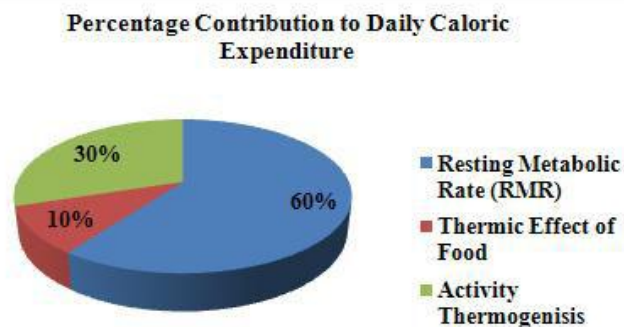


Figure 2.1: Major components of total energy expenditure (Morrison *et al.*, 1996:640).

### 2.4.1. Resting metabolic rate and fat-free mass

Fat-free mass (organ, skeletal and bone mass) is the main contributor of energy consumption and total-body FFM is commonly used as a surrogate for metabolically active tissue (Gallagher *et al.*, 2006:1062). The brain, liver, kidneys and heart contribute to 60-70% of RMR, although the combined weight of these metabolic active organs is less than 6% of total body weight (Gallagher *et al.*, 1998:249). Skeletal muscle mass is responsible for 20-30% of RMR and comprises 40-50% of total body mass (Gallagher *et al.*, 1998:249). In comparison, African Americans have greater amounts of bone and skeletal muscle mass and similar or smaller amounts of total body fat (Gallagher *et al.*, 2006:1063).



African Americans have a smaller mass of the most metabolically active organs and, therefore, a lower proportion of FFM as high-metabolic-rate (HMR) organs [sum of liver, heart, spleen, kidneys and brain], than Caucasians (Gallagher *et al.*, 2006:1062; Gallagher *et al.*, 1998:249). As the metabolic rate of the organs are 15-25 times that of muscle the contribution of organs to RMR (60%) is 2.4 times higher than muscle (20-25%) per unit mass (Illner *et al.*, 2000:309). Illner *et al.* (2000:309) concluded that organ size contributes significantly to RMR in adolescents. Hunter *et al.* (2000:500) found that ethnic differences in the composition of trunk lean mass (TLM) explain the ethnic differences in RMR which is supported by Tershakovec *et al.* (2002:870) who suggest that ethnic differences in trunk and lean limb tissue partially account for the ethnic differences in RMR. The reason for the persistent ethnic group differences in RMR among children and adolescents are not clear (Tershakovec *et al.*, 2002:870).

DeLany *et al.* (2006:867) identified several variables of energy metabolism that predicted change in percentage body fat over 2 years in a longitudinal study of energy metabolism in children during the pubertal growth spurt. Variables included RMR, total daily energy expenditure (TDEE) and thermic effect of food (TEF), gender and ethnicity (DeLany *et al.*, 2006:867).

### 2.4.2 Resting metabolic rate and body composition components

A significant relationship between BC and RMR have been indicated (Tremblay, 2010:130; Gallagher *et al.*, 2006:1062; Tershakovec *et al.*, 2002:870; Sun *et al.*, 2001:313). Individual variation in RMR is primarily attributable to the amount of lean body mass, which explains a much greater fraction of the variance in RMR than any other factor according to Tremblay (2010:130). Accordingly, obese individuals are expected to have an increased RMR, which has been interpreted by some obesity specialists as an absence of thermogenic effect in these persons (Tremblay, 2010:130).

Body composition changes with age, even in the absence of changes in body weight and BMI (St-Onge & Gallagher, 2010:152). Studies show that fat mass increases and muscle mass decreases with age, but the reason for the changes is still unclear. St-Onge and Gallagher (2010:152) proposed that reductions in RMR and fat oxidation could lead to

changes in body composition. Alternatively they stated that changes in body composition with aging may lead to a decrease in RMR. There is indirect evidence proposing that the RMR of individual organs is lower in older individuals compared to their younger counterparts (St-Onge & Gallagher, 2010:152). According to St-Onge and Gallagher (2010:152), with aging there is a reduction in individual organs/tissue mass and in tissue specific organ metabolic rate that contributes to the reduction in RMR which leads to changes in body composition including increased fat mass and reduced fat-free mass. Therefore, the lower RMR in older individuals may be due in part to the slowed organ metabolic rates, which could contribute to changes in FM and FFM (St-Onge & Gallagher, 2010:155).

Sun *et al.* (2001:313), however, did not find a lower RMR in African Americans than in White prepubertal and pubertal children. A possible reason for the contrast in results may have been a failure to assess Tanner stage accurately in the different ethnic groups that mature at different rates or differences in maturation that cannot be easily assessed (Sun *et al.*, 2001:313).

### 2.4.3 Resting metabolic rate and gender differences

Boys have a higher RMR than girls, even after adjustment for differences in body weight (DeLany *et al.*, 2004:273; Sun *et al.*, 2001:308). DeLany *et al.* (2004:273) established that ethnic differences in RMR were more apparent in boys than in girls. Morrison *et al.* (1996:640) stated that the ethnic difference in RMR in girls is most prominent in pubertal stage. They proposed a growth model that refers to a process during childhood, more pronounced in girls than in boys, in which pre-obese children have a faster decrease in RMR per kilogram of body weight and a subsequent increased growth rate and development. This explains the earlier adolescence in pre-obese children (Morrison *et al.*, 1996:641). DeLany *et al.* (2006:864) found that in boys and girls of the same age, girls had a significantly higher Tanner stage score (were sexually more mature) than boys, and African American children had a significantly higher Tanner stage score than Caucasian children. DeLany *et al.* (2006:867) confirmed that metabolic rate is a predictor of fat gain, but the direction of the effect differed between boys and girls. In boys, a low RMR predicted fat gain, in contrast girls who gain more fat have a higher intake of energy to

provide for higher metabolism and accumulation of additional fat (DeLany *et al.*, 2006:868).

#### 2.4.4. Age, maturation and resting metabolic rate

Adolescence is characterized by rapid growth which induces changes in metabolic rate as a result of anatomic, physiologic and behavioural alterations (Bandini *et al.*, 2004:1262; Bitar *et al.*, 1999:1209). Basal metabolism declines throughout childhood and reaches adult values late in adolescence (Butte *et al.*, 2007:2660). The decline in basal metabolism relative to body weight is the result of change in the metabolic rate of individual organs and tissues and to the degree of difference in growth rates of organs with high metabolic rates relative to those with lower metabolic rates (Butte *et al.*, 2007:2661). Thus the differences in energy expenditure between organ and skeletal mass could explain the decline in RMR with maturation (Tershakovec *et al.*, 2002:870; Sun *et al.*, 2001:313).

Morrison *et al.* (1996:641) found a lower RMR in young African American girls, despite them having a higher lean body mass, which could indicate a lower RMR result in a faster accumulation of body mass and, therefore, an earlier sexual maturation. In the development of obesity the onset of maturation is an important factor, as an earlier maturation in girls is associated with a higher BMI compared to late maturing girls (Morrison *et al.*, 1996:641). It has been shown that African American girls have an earlier onset of puberty than Caucasian girls and African American woman ultimately have a higher prevalence of obesity than Caucasian woman (Morrison *et al.*, 1996:641).

Tershakovec *et al.* (2002:870) identified an inverse relation between RMR and age. Resting metabolic rate per kilogram body weight declines during growth and development, possibly as a result of the changing composition of fat-free mass (Tershakovec *et al.*, 2002:870). The metabolically active organs (brain, liver kidneys and heart) decrease in proportion to the fat-free mass as the skeletal muscle increases with age and maturation (St-Onge & Gallagher, 2010:152; Tershakovec *et al.*, 2002:870). The decline in RMR relative to body weight closely parallels the changes in total organ weight relative to body weight (Tershakovec *et al.*, 2002:869).

A possible reason for the effect of maturation on RMR during puberty is the different metabolic contributions of muscle and organ mass (Illner *et al.*, 2000:309). Illner *et al.* (2000:309) concluded that organ mass contributes significantly to RMR in adolescents. During puberty skeletal muscle is accumulated more rapidly than organ mass which could lead to the decrease in RMR as the proportion of relatively less demanding skeletal muscle component of LM increases with regards to the metabolically active organ mass (Sun *et al.*, 2001:308).

Morrison *et al.* (1996:639) found a lower RMR in pre-pubertal girls than for pubertal and post-menarcheal girls, whereas Sun *et al.* (2001:313) described a lower RMR as children matured in Tanner stage, independent of age. Tershakovec *et al.* (2002:869), however, found no significant association between pubertal status and RMR, although there was an age related decrease in RMR. This age-related decrease in RMR could have significant implications (Tershakovec *et al.*, 2002:869). The lower RMR of older children suggests that weight management interventions for pediatric obesity may have a greater success rate in younger children, who have a higher RMR (Kruger *et al.*, 2004:357; Tershakovec *et al.*, 2002:869).

#### 2.4.5. Ethnic differences in resting metabolic rate

It is well documented that African Americans have a lower RMR than White children and adolescents (Sun *et al.*, 2001:308; Kaplan *et al.*, 1996:643; Morrison *et al.*, 1996:638). As RMR comprises  $\pm 65\%$  of total daily energy expenditure, the daily differences in RMR observed, if not compensated for by a lower energy intake, can over a prolonged period contribute to the greater prevalence of obesity in African Americans (Gallagher *et al.*, 2006:1062; Sun *et al.*, 2001:314; Wurmser *et al.*, 1998:797; Kaplan *et al.*, 1996:646).

Morrison *et al.* (1996:639) established a model for explaining the variance in RMR which included LBM, ethnicity and maturation stage. It was indicated that a significant difference in RMR exists between Caucasian and African American girls after accounting for the effects of LBM and pubertal maturation, with Caucasian girls having a higher RMR than their African American counterparts. Morrison *et al.* (1996:640) also indicated that the ethnic differences in bone mass did not explain the differences in RMR.

Ethnic differences in RMR could be explained by differences in body size and body mass (Morrison *et al.*, 1996:641). Tremblay (2010:130) and Morrison *et al.* (1996:641) agree that lean body mass (LBM) is the most important body composition factor for explaining the variance in RMR and that bone is metabolically less active than lean body mass. In this study it was also reported that African American girls have a greater bone mass than Caucasian girls for any given level of fat-free mass [FFM] (Morrison *et al.*, 1996:641). Caucasian children have a larger FFM than African American children and a smaller bone mineral mass than African American children (Sun *et al.*, 2001:314). Bone has a low metabolic activity, therefore, the greater bone mass may be a cause for a lower RMR in African American children with similar amounts of FFM (Sun *et al.*, 2001:314; Morrison *et al.*, 1996:641). The lower RMR in African Americans can, therefore, be ascribed to differences in the composition of the body's FFM compartment (Gallagher *et al.*, 2006:1062; Kaplan *et al.*, 1996:646, Gallagher *et al.*, 1998:249).

### 2.4.6 The importance of a low or high resting metabolic rate and body composition by ethnicity

Several studies suggest that African American children have lower adjusted resting metabolic rates than their Caucasian counterparts in pre-pubertal and pubertal ages (Bandini *et al.*, 2002:1044; Yanovski, 2001:149; Kaplan *et al.*, 1996:646; Morrison *et al.*, 1996:641). Bandini *et al.* (2002: 1046) stated that a reduction in energy expenditure in the pre-obese state could be a risk factor for the subsequent development of obesity. The reduced energy expenditure in pre-obese African American children could, therefore, contribute to the higher prevalence of obesity seen among African American girls than among Caucasian girls (Kruger *et al.*, 2004:357; Tershakovec *et al.*, 2002:867; Sun *et al.*, 2001:314). Young African American girls have a lower RMR than young Caucasian girls, despite having a higher muscle mass, indicating that a lower RMR could result in a faster accumulation of body mass and, therefore, earlier maturation. The ethnic differences in RMR observed by Morrison *et al.* (1996:641) could contribute to differences in the prevalence of obesity in African American and Caucasian children. It could, therefore, be concluded that African American girls are the most predisposed to obesity having the lowest RMR.

## 2.5 Resting metabolic rate and obesity

Despite the global epidemic in childhood obesity, the energy metabolism of overweight and obese children and adolescents has not been studied thoroughly (Butte *et al.*, 2007:2660). Previous cross-sectional studies examining RMR in obese and non-obese children have reported discrepant findings (Butte *et al.*, 2007:2660). RMR is mostly found to be higher in obese than in non-obese children when absolute values (kJ/d) are compared (Butte *et al.*, 2007:2663; Stensel *et al.*, 2001:369). After control for FFM, most studies reported that RMR did not differ significantly between obese and non-obese children, although some studies still reported higher RMR values in the obese children (Butte *et al.*, 2007:2663; Stensel *et al.*, 2001:369).

Butte *et al.* (2007:2663) reported that the higher rate of energy expenditure in overweight adolescents was largely accounted for by differences in body size and body composition which is supported by Stensel *et al.*, (2001:371) that found that RMR did not differ significantly between obese and non-obese adolescent boys after FM and FFM was controlled for. A lack of control for subject characteristics such as sex, age, sexual maturation, and body composition, as well as other factors such as physical activity, energy balance and diet composition could explain conflicting results regarding differences in RMR in obese and non-obese adolescents (Butte *et al.*, 2007:2660).

The following list (Table 2.3) aims to give an overview of the different findings of various studies regarding the RMR in obese and non-obese children and adolescents.

Table 2.3 Research on RMR in obese and non-obese children and adolescents

Author (s)	Title of study	RMR ↑ in obese than non-obese	RMR ↓ in obese than non-obese	FFM ↑ in obese than non-obese	FFM controlled: RMR ↑ in obese than non-obese	FFM controlled: RMR ↓ in obese than non-obese
Bandini <i>et al.</i> , 1990:198	Energy expenditure in obese and non-obese adolescents	✓		✓	✓	
Epstein <i>et al.</i> , 1989:331	Resting metabolic rate in lean and obese children: relationship to child and parent weight and percent overweight change	✓				
Maffeis <i>et al.</i> , 1993:481	Meal induced thermogenesis in lean and obese prepubertal children	✓				✓
Maffeis <i>et al.</i> , 1995:16	Increased fat oxidation in prepubertal obese children: a metabolic defence against further weight gain?	✓		✓		✓
Molnar & Schultz, 1997:367	The effect of obesity, age puberty and gender on resting metabolic rate in children and adolescents	✓		✓	✓	
Schultz <i>et al.</i> , 1999:858	Whole-body protein turnover and resting energy expenditure in obese, prepubertal children	✓		✓		✓
Treuth <i>et al.</i> , 1998:440	Energy expenditure and physical fitness in overweight vs	✓		✓		✓

	non-overweight prepubertal girls					
DeLany <i>et al.</i> , 1995:67	Energy expenditure in lean and obese prepubertal children		✓			
Maffeis <i>et al.</i> , 1991:114 6	Basal energy expenditure in obese and normal weight schoolchildren		✓			✓
Stensel <i>et al.</i> , 2001:370	Resting metabolic rate in obese and nonobese Chinese Singaporean boys aged 13-15 years	-	-		✓	

↑, higher; ↓, lower; -, no significant difference; **RMR** – resting metabolic rate; **FFM** – fat-free mass.

Possible explanations for the different findings above include (Stensel *et al.*, 2001:369):

1. Methods used to measure body composition,
2. criteria used to determine obesity, and
3. controlling for differences in body composition or size when comparing RMR values.

## 2.6 Summary

In summary, it is clear from the literature that body composition and RMR differs for ethnic groups. The difference in prevalence of adolescent obesity among ethnic groups may be explained among other factors by genetics, physiology, culture, socio-economic status and the environment (Goedecke & Jennings, 2005:546). Obesity develops as an interaction between a genetic predisposition and certain environmental factors, such as high-fat diets and low total daily energy expenditure (TDEE) caused by low physical activity. Resting metabolic rate (RMR) is the major determinant of total daily energy expenditure (Morrison *et al.*, 1996:640) and is mainly determined by body size and body composition. Research findings show that a low TDEE is an important risk factor for weight gain and obesity (Wurmser *et al.*, 1998:797; Kaplan *et al.*, 1996:646). A low



relative RMR, expressed in relation to fat-free mass (FFM), has been found to be a risk factor for subsequent weight gain (Tremblay, 2010:130).

The literature shows that African Americans have a lower RMR than Caucasians, but there is limited data for obese children and adolescents, as well as for boys regarding RMR (Jones *et al.*, 2004:780; Tershakovec *et al.*, 2002:867). Some investigators suggest that the relatively low RMR in African American children and adolescents could be a predisposing factor for long-term weight gain and obesity, but there is limited data available (Tershakovec *et al.*, 2002:867). If future research confirms a lower RMR in African American than in Caucasian children during pubertal development, the lower metabolism could be related to the increased prevalence of obesity in the African American population (Sun *et al.*, 2001:314). Ethnic differences related to trunk lean body mass (and the high metabolic activity of visceral organs included in the trunk lean body mass) could account for differences in RMR in adult African American and Caucasian woman, but this, however, has not been studied in children and adolescents (Tershakovec *et al.*, 2002:867). DeLany *et al.* (2004:268) observed ethnic and gender differences in children where Caucasian children had a higher RMR than African American children after accounting for differences in body composition. Tershakovec *et al.* (2002:867) suggest that the low RMR in African American children and adolescents could be a predisposing factor for long-term weight gain and obesity, but there is limited data available. If further investigations confirm a lower RMR in African American than in Caucasian children during pubertal development, the lower metabolism could be related to the increased prevalence of obesity in the African American population (Sun *et al.*, 2001:314).

As the health and economic consequences of obesity are so debilitating and prevalent in the South African population, it is important to determine whether a low RMR in children can in the long term lead to obese older children and adults (Steyn *et al.*, 2005:12). The World Health Organisation (WHO) recommends that developing countries monitor the trend of obesity in children, since these are risk factors for chronic diseases in adulthood (WHO, 2007). The treatment of adult obesity has poor results and, therefore, assessment strategies should seek to identify children and adolescents who are prone to overweight/obesity to prevent the public health problem of obesity at an earlier stage (Caprio *et al.*, 2008:2212; Kruger *et al.*, 2004:357; Jerum & Melnyk, 2001:609; Williams, 2001:158).

The increasing prevalence of child and adolescent obesity, combined with the above mentioned, warrants the need to detect children and adolescents at risk for overweight or high relative fat mass as early as possible. In South Africa despite the existence of both obesity and underweight in children (Reddy *et al.*, 2010:42; Monyeki, 2006:116), limited research has been published with regards to body composition and RMR in adolescents living in the Tlokwe municipality of the North West Province. Considering the above mentioned and a scarcity of South African data available for adolescents of different ethnicities, the following research questions arise. Firstly, are there ethnic and gender differences regarding body composition and RMR in black and Caucasian adolescents, specifically from the Tlokwe municipality? Secondly, is there a significant relationship between anthropometric indicators of BC and RMR?

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## Chapter 3



### **Body composition and resting metabolism rates of black and Caucasian South African adolescents: the PAHL-Study**

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## Abstract

The objectives of this study were firstly to determine the body composition (BC) and resting metabolic rate (RMR) status of 14 year old black and Caucasian South African adolescents in the Tlokwe municipality of the North West Province, South Africa and secondly, to determine the relationship between anthropometric indicators of body composition and resting metabolic rate in these South African adolescents. Participants are a subgroup of 73 (black,  $n = 57$  and Caucasian,  $n = 16$ ) adolescents, drawn from the Physical Activity and Health Longitudinal Study (PAHLS) baseline data. The general aim of the Physical Activity and Health Longitudinal Study (PAHLS) is to investigate physical activity and health determinants in adolescents living within the Tlokwe municipality of the North West Province over the next 5 years. Anthropometric measurements included stature, body mass, triceps and subscapular skinfolds, and waist girth and were measured according to ISAK procedures, and subsequently body mass index (BMI), percentage body fat (%BF), fat free mass (FFM) and waist-to-height-ratio (WHTR) were calculated. Participants were categorized as overweight, normal weight and underweight/thinness based on Cole *et al.* (2000) and Cole *et al.* (2007) respectively. Resting metabolic rate (RMR) was measured with the FitMate Pro Indirect Calorimetry (Cosmed). The results indicated that 11% of the total group of adolescents were overweight. Forty seven percent (47%) of the black adolescents were underweight, 9% overweight and 44% normal weight. In the Caucasian participants, 13% were underweight, 25% overweight and 63% normal weight. The Caucasian adolescents were significantly ( $p < 0.05$ ) taller, heavier and had a higher %BF, WHTR, FFM and RMR than the blacks of both genders. Boys of both ethnicities had a higher RMR than the girls, with black girls having the lowest RMR. Obese adolescents of both ethnicities had a higher FFM and RMR than the non-obese adolescents. Non-significant relationships between body composition and RMR were indicated, though the relationships were in the expected directions. It was evident from the results that FFM, though not significant, was highly associated with RMR in the overweight adolescents. From the results of this study it can be concluded that ethnic differences in body composition and resting metabolism exists. Interestingly, the paradox of both underweight and overweight between the blacks and Caucasians was observed. Additionally, the overweight Caucasian adolescents differed significantly from their black counterparts in body composition and RMR. Whether the observed ethnic differences in RMR predict future weight gain and obesity awaits the results of longitudinal analyses.

**Keywords:** Resting metabolic rate (RMR), body composition (BC), ethnicity, adolescents, obesity

## Introduction

The increasing prevalence of obesity is not only a problem for developed countries, but also an increasing problem in many developing countries (Monyeki, Van Lenthe & Steyn, 1999; Mukuddem-Petersen & Kruger, 2004; Steyn, Labadrios, Maunder, Nel & Lombard, 2005; National Centre for Health Statistics, 2007). Obesity in South Africa is not limited to the adult population, but commences during childhood, especially in woman (Monyeki *et al.*, 1999; Goedecke & Jennings, 2005). Obesity related risk factors and diseases formerly seen only in adults are increasingly being recognized in obese adolescents (Caprio, Daniels, Drewnowski, Kaufman, Palinkas, Rosenbloom & Schwimmer, 2008). Although childhood obesity is increasing in all ethnic groups, its prevalence is higher in non-Caucasian populations (Caprio *et al.*, 2008). Obesity results from a chronic imbalance between energy intake and expenditure (World Health Organisation, 2007). Obesity develops as an interaction between a genetic predisposition and certain environmental factors, such as high-fat diets and low total daily energy expenditure (TDEE) caused by low physical activity. Resting metabolic rate (RMR) is the major determinant of TDEE (Morrison, Alfaro, Khoury, Thorton & Daniels, 1996) and is mainly determined by body size and body composition. Research findings show that a low TDEE is an important risk factor for weight gain and obesity (Morrison *et al.*, 1996; Bandini, Must, Spandano & Dietz, 2002). A low relative RMR, expressed in relation to fat-free mass (FFM), has been found to be a risk factor for subsequent weight gain (Tremblay, 2010).

According to Morrison *et al.* (1996), the development of obesity is associated with ethnic differences in resting energy expenditure (resting metabolic rate [RMR]). RMR comprises 60-80% of total daily energy expenditure (TDEE) and if affected or altered could lead to obesity (Morrison *et al.*, 1996; Sun, Gower, Batolucci, Hunter, Figueroa-Colon & Goran, 2001; Bandini *et al.*, 2002; Tershakovec, Kuppler, Zemel & Stallings, 2002; Kruger, Kruger, & Macintyre 2004). A low RMR would, therefore, pre-dispose an ethnic group to obesity and the health related consequences associated with obesity (Kaplan, Zemel & Stallings, 1996; Wurmser, Laessle, Jacob, Langhard, Uhl, Muller & Pirke, 1998). Tremblay (2010), however, indicated that obese individuals are expected to have an increased RMR, which has been interpreted by some obesity specialists as an absence of



thermogenic effect in these persons. Butte, Puyau, Vohra, Adolph, Metha & Zakeri (2007) reported that the higher rate of energy expenditure in overweight adolescents was largely accounted for by differences in body size and body composition which is supported by Stensel, Lin & Nevill (2001) who found that RMR did not differ significantly between obese and non-obese adolescent boys after FM and FFM was controlled for.

DeLany, Bray, Harsha & Volaufova (2006) confirmed that metabolic rate is a predictor of fat gain, but the direction of the effect differed between boys and girls. It is been suggested that ethnic differences related to trunk lean body mass (and the high metabolic activity of visceral organs included in the trunk lean body mass) could account for differences in RMR in adult African American and Caucasian woman, but this, however, has not been studied in children and adolescents (Tershakovec *et al.*, 2002). The distribution of lean body mass also differs significantly between African American and Caucasian children and ethnic differences in RMR were eliminated by including the distribution of lean body mass (Morrison *et al.*, 1996; DeLany, Bray, Harsha & Volaufova., 2004; Tremblay, 2010). Several studies suggest that African American children have a lower adjusted RMR than their Caucasian counterparts in the pre-pubertal and pubertal ages (Morrison *et al.*, 1996; Kaplan *et al.*, 1996; Yanovski, 2001; Bandini *et al.*, 2002). The lower RMR in African Americans could be ascribed to differences in the composition of the body's fat free mass (FFM) compartment (Kaplan *et al.*, 1996, Gallagher, Belmonte, Deurenberg, Wang, Krasnow, Pi-Sunyer & Heymsfield, 1998; Gallagher, Albu, He, Heshka, Boxt, Krasnow & Elia, 2006). DeLany *et al.* (2004) observed ethnic and sex differences in children where Caucasian children had a higher RMR than African American children after accounting for differences in body composition. Individual variation in RMR is primarily attributable to the amount of lean body tissue, which explains a much greater fraction of the variance in RMR than any other factor (Tremblay, 2010). DeLany *et al.* (2004) reported that ethnic differences in RMR were more apparent in boys than in girls. Boys have a higher RMR than girls, even after adjustment for differences in body weight (Sun *et al.*, 2001; DeLany *et al.*, 2004). According to Morrison *et al.* (1996), the ethnic differences in RMR in girls are most pronounced in pubertal stage.

South Africa is a country reflecting two extremes, namely obesity in children or adolescents on the one side of the spectrum (5.3% of adolescents), co-existing with stunting and underweight (8.4% of adolescents) on the other side (Healthy Active Kids South Africa, 2007; Reddy, James, Sewpaul, Koopman, Funani, Sifunda, Josie, Masuka, Kambaran & Omardien, 2010; World Health Organisation, 2011). Despite the global epidemic in childhood obesity, the energy metabolism of overweight and obese children or adolescents has not been studied thoroughly (Tershakovec *et al.*, 2002; Jones, Shen, St-Onge, Gallagher, Heshka, Wang & Heymsfield, 2004; Butte *et al.*, 2007). These findings, combined with the increasing prevalence of childhood and adolescent obesity is reason enough to detect children and adolescents at risk for overweight or high relative fat mass as early as possible (Delany, Bray, Harsha & Volaufova, 2002; Kruger *et al.*, 2004; DeLany *et al.* 2006). Early detection will enable early intervention strategies to prevent excessive body mass and fat gain before adolescence (Nooyens, Koppes, Visscher, Twisk, Kemper & Schuit, 2007; Taeymans, Hebbelinck, Borms, Clarys & Duquet, 2008). In South Africa despite the existence of both obesity and underweight in children (Monyeki, 2006; Reddy *et al.*, 2010), limited research has been published with regards to body composition and RMR in adolescents and the possible association of RMR with body composition in children and adolescents living in the Tlokwe municipality of the North West Province. The objectives of this study, therefore, were firstly to determine the body composition and resting metabolic rate (RMR) of 14 year old South African black and Caucasian adolescents and secondly, to determine the relationship between anthropometric indicators of body composition and resting metabolic rate in these South African adolescents from the Tlokwe municipality of the North West Province, South Africa.

## **Methods**

### **Participants**

The Physical Activity and Health Longitudinal Study (PAHLS) is an observational multidisciplinary longitudinal study that started in 2010. Initially eight schools were recruited to take part in the study based on the high (Town) and low socio-economic (Township) status of which two schools from high socio-economic refused, as such only six schools agreed to take part. From the six schools a total of 310 boys and girls aged 14

years old representing high socio-economic status and low socio-economic status, took part in the baseline measurements. The participants were an availability group and the results should be interpreted with the sampling taken in consideration.

The aim of the study was to describe the development of physical activity and determinants of health risk factors in 14 year-old adolescents attending high schools in Potchefstroom areas of the North West Province of South Africa. As such a sub-sample consisting of seventy three ( $n = 73$ ) healthy participants were randomly selected from a baseline data of 310 adolescents who were part of the ongoing Physical Activity and Health Longitudinal Study (PAHLS). Of the participants, 33 boys ( $n = 25$  black and  $n = 8$  Caucasian adolescent boys) and 40 girls ( $n = 32$  black and  $n = 8$  Caucasian adolescent girls) from the Potchefstroom areas in the North West Province participated in the study. All healthy adolescents who were born in 1996 were included in the study. For the purpose of the present study exclusion criteria for participation in the study included any diagnosed/known acute or chronic disease that affects body composition or RMR and the use of any medication that affects body composition or RMR.

### **Procedures**

Prior to the study permission to conduct the measurements was granted by the District Manager of the Department of Education in Potchefstroom. In addition, the Ethics Committee (*Ethics no: NWU-0058-01-A1*) of the Potchefstroom Campus of the North-West University granted approval for the study. The participating schools were contacted and briefed about the purpose of the study and subsequently informed consent was given by the school authorities, the parents and the pupils of the participating schools. The pupils reported at their schools after an overnight fast. The demographic information for each participant was collected after which the anthropometric measurements (stature, body mass, skinfolds and girths) were taken. After the anthropometric measurements the RMR was measured.

### **Measurements**

*Anthropometry and body composition.* Height and weight were measured according to the standard procedures described by the International Society for Advancement of

Kinanthropometry (ISAK) (Marfell-Jones, Olds, Stewart & Carter, 2006). The maximum stretched stature of the subject was measured to the nearest 0.1 cm with a stadiometer. As the subject inhaled, the stretched stature was measured with the head in the Frankfort plane. Body mass was calculated to the nearest 0.1 kg with an electronic scale with the subject wearing minimal clothing. Body Mass Index (BMI) was calculated as weight divided by height squared ( $\text{kg}\cdot\text{m}^{-2}$ ). Age-specific BMI for children was used to determine overweight, normal weight and underweight/thinness respectively (Cole, Bellizzi, Flegal & Dietz, 2000; Cole, Flegal, Nicholls & Jackson, 2007). Skinfolts were taken according to the standard procedures of ISAK (Marfell-Jones *et al.*, 2006). The triceps and subscapular skinfolts were measured to the nearest 0.2 mm with a Harpenden (British Indicators, UK) skinfold caliper and the average of the two measurements was used. The equations of Slaughter, Lohman, Boileau, Horswill, Stillman, Van Loan & Bembien (1988) which are used for children and adolescents from different ethnic groups, were used to calculate percentage body fat (%BF) and the percent-fat charts for boys and girls respectively were used to classify them according to %BF (Lohman, 1987). Fat free mass (FFM) was obtained by subtracting body fat mass from total body weight (body weight - total body fat). Girths were taken to the nearest 0.1 cm using the cross-hand technique with a Lufkin non-stretch steel measuring tape (Cooper Tools, Apex, NC). Waist girth and stature were used to calculate the waist-to-height ratio (WHTR). Yan, Bingxian, Hua, Jianghong, Jun, Dongliang, Yujian, Ling, Yanying, Kaiti, Xiaohai & Da (2007) proposed using the cut-off points of WHTR of 0.485 for boys and a WHTR of 0.475 for girls as an accurate indicator to identify obesity.

*Resting metabolic rate (RMR).* The FitMate Pro (Cosmed, Rome, Italy) indirect calorimetry was used to determine the RMR of the participants quickly and accurately (Nieman, Austin, Benezra, Pearce, Mcinnis, Unick & Gross, 2006). The system measured oxygen consumption by sampling expired gas by means of a dynamic mixing chamber. It immediately calculated RMR and automatically printed the results. The FitMate Pro used standard metabolic formulas to calculate oxygen uptake, and energy expenditure with a fixed respiratory quotient (RQ) of 0.85 (Nieman *et al.*, 2006). FitMate is validated against the “gold standard” Douglas bag technique and self calibrated in 20 seconds prior to each measurement. RMR was calculated after the body mass and stature of each subject was

entered and the subject rested for a ten minute period. Measurements were taken in a dimly lit room at a comfortable temperature. The first minute of sampling was discarded to ensure that subjects breathed normally

and continuously for ten minutes through the FitMate mask during sampling.

### **Statistical analysis**

Descriptive statistical analysis was performed to present the means and standard deviation as well as the frequencies of the studied variables. An independent t-test was used to compare the two groups (black vs. Caucasian, boys and girls respectively) with regards body composition and RMR. Analysis of variances (ANOVA) was calculated to determine the differences between the three BMI groups for boys and girls, and by ethnic differences. To study the relationship between RMR and body composition, Pearson correlations coefficients (adjusted for gender and ethnicity) were calculated. Significant difference levels were set at  $p < 0.05$ .

### **Results**

The results show that 42.4% (n = 31) adolescents from the total group were in the underweight category, 46.6% (n = 34) were in the normal weight category and 11.0% (n = 8) were in the overweight category (Figure 1).

PLACE FIGURE 1 HERE

The data were also analyzed separately for gender and ethnicity (Figures 2 and 3). The results (Figure 2) indicate significant ethnic differences between the black and Caucasian adolescents regarding the underweight category. Forty nine percent (49.0%) of the black (n = 28) adolescents were underweight compared to 19.0% (n = 3) of Caucasian adolescents. The largest percentage of adolescents was in the normal weight category with 42.0% (n = 24) for black adolescents and 62.0% (n = 10) for Caucasian adolescents. With regards to the overweight category, 9.0% (n = 5) of black adolescents and 19.0% (n = 3) of Caucasian adolescents were overweight.

PLACE FIGURE 2 HERE

The descriptive statistics results show that 52.0% (n = 13) of black adolescent boys were underweight compared to 25.0% (n = 2) of Caucasian adolescent boys being underweight.

Forty percent (n = 10) of black adolescent boys and 62.0% (n = 5) of Caucasian adolescent boys were in the normal weight category. The results illustrate that 8.0% (n = 2) of black adolescent boys and 13.0% (n = 1) of Caucasian adolescent boys were overweight. With regards to the adolescent girls, 47.0% (n = 15) of black girls and 12.0% (n = 1) of Caucasian girls were in the underweight category. Forty four percent (n = 14) of black adolescent girls and 63.0% (n = 5) of Caucasian adolescent girls were in the normal weight category. The Caucasian adolescent girls presented with the highest percentage of overweight, with 25.0% (n = 2) of Caucasian girls being classified as overweight in contrast to only 9.0% (n = 3) of black girls being in the overweight category. The largest percentage of black adolescents were underweight (52.0% of black boys and 47.0% of black girls) whereas the largest percentage of Caucasian adolescents were in the normal weight category (62.0% of Caucasian boys and 63.0% of Caucasian girls).

PLACE FIGURE 3 HERE

The results of the average percentage body fat (%BF) indicate significant ethnic and gender differences between the black and Caucasian adolescents (Figure 4). Boys of both ethnicities have a lower percentage body fat than the girls. The Caucasian adolescents have a significantly higher percentage body fat than the black adolescents for both genders. Black boys have the lowest %BF ( $18.9 \pm 8.12\%$ ) and Caucasian girls have the highest %BF ( $31.0 \pm 8.41\%$ ). According to the percent-fat charts (triceps plus subscapular skinfolds) for boys the Caucasian boys ( $21.74 \pm 10.64\%$ ) are classified as having a moderately high %BF (19-25%) and black boys ( $18.09 \pm 8.12\%$ ) are classified with a %BF in the optimal range (10-20%) (Lohman, 1987). Caucasian girls are classified as having a high %BF (30-35.5%) and black girls ( $24.27 \pm 8.92\%$ ) are in the optimal range (15-25%) according to percent fat charts for girls (triceps plus subscapular skinfolds) (Lohman, 1987).

PLACE FIGURE 4 HERE

Regarding the descriptive characteristics of body composition and RMR for the total group (Table 1), the Caucasian adolescents were significantly ( $p < 0.05$ ) taller, heavier, had a higher BMI, WHTR and RMR than the black adolescents. The mean FFM of the Caucasian adolescents ( $37.67 \pm 12.79$  kg) was significantly higher than the mean FFM of the black adolescents ( $26.44 \pm 7.88$  kg).

## PLACE TABLE 1 HERE

The descriptive characteristics of BC and RMR for boys and girls by ethnicity (Table 2) indicated significant gender differences. Girls of both ethnicities were heavier, had a higher BMI, a bigger WHTR and a higher percentage of body fat than the boys. Girls of both ethnicities had a lower FFM and RMR than the boys. Caucasian girls had a significantly ( $p < 0.05$ ) higher body mass, stature, BMI, FFM and RMR than the black girls. The Caucasian adolescent boys had significantly ( $p < 0.05$ ) higher body mass, stature, FFM and RMR than the black boys. The ethnic differences in RMR were more apparent when Caucasian boys were compared with black boys. Caucasian boys had the highest FFM ( $40.72 \pm 12.48$  kg) and the highest RMR ( $1713.38 \pm 560.16$  kcal/day), in comparison with black girls who had the lowest FFM ( $23.84 \pm 6.14$  kg) and lowest RMR ( $1226.72 \pm 240.82$  kcal/day).

## PLACE TABLE 2 HERE

Table 3 shows the ANOVA calculated to determine the differences between the three BMI groups by ethnicity. The overweight/obese adolescents of both ethnicities had significantly higher values for all measures of body composition, as well as a higher RMR than the normal and underweight adolescents. The results further indicate that the RMR and FFM of the Caucasian adolescents were significantly higher than that of their counterpart black adolescents in the normal and overweight/obese groups. The overweight/obese group of both ethnicities had a higher FFM and RMR than the normal and underweight group. The obese/overweight Caucasian adolescents had the highest FFM ( $55.74 \pm 10.24$  kg) and RMR ( $1976.33 \pm 447.50$  kcal/day). The RMR of the underweight black adolescents ( $1166.57 \pm 200.98$  kcal/day) was higher than that of the Caucasian adolescents ( $1108.33 \pm 335.08$  kcal/day), but not statistically significant ( $p < 0.05$ ).

## PLACE TABLE 3 HERE

Table 4 presents the results on correlation coefficients for RMR and parameters of body composition for underweight, normal and overweight adolescents. The results show high non-significant positive correlations between RMR and BMI and FFM in the overweight group. After adjusting for gender and ethnicity a high non-significant negative relationship between RMR and FFM in the overweight group was observed (Table 5). A significant correlation was found between RMR and FFM in the normal weight group.

PLACE TABLE 4 HERE

Table 5 shows the correlation coefficients for the association of RMR and body composition parameters adjusted for gender and ethnicity. In the underweight group RMR and FFM still had the highest positive correlation after adjusting for gender and ethnicity, and RMR and %BF still had the highest negative correlation. In the normal weight group, the highest positive correlation was found between RMR and BMI after adjustment for gender and ethnicity. Regarding the overweight group, the highest positive correlation was between RMR and BMI and the highest negative correlation between RMR and FFM.

PLACE TABLE 5 HERE

### **Discussion**

The present study shows that 11% of the total group of adolescents were overweight/obese and these results show trends of overweight/obesity which seem to be congruent with previous studies done in South Africa (Kruger *et al.*, 2004; Healthy Active Kids South Africa, 2007; Reddy *et al.*, 2010; Kruger *et al.*, 2004). The Report Card on the Physical Activity, Nutrition and Tobacco use for South African Children and Youth (2007) reported that more than 30% of adolescent South African girls and 10% of South African boys are obese (Healthy Active Kids South Africa, 2007). The study further indicated the prevalence of underweight in this population, with a higher prevalence of underweight among the black adolescents (Monyeki *et al.*, 1999; Monyeki, 2006; Reddy *et al.*, 2010). The above mentioned results indicate the double burden of disease of obesity and underweight in Africa (Reddy *et al.*, 2010; WHO, 2011). The present results were in agreement with previous findings (Gasperino, 1996; DeLany *et al.*, 2004; Gallagher, Kuznia, Heshka, Albu, Heymsfield, Goodpaster, Visser & Harris, 2005; Torriani & Grinspoon, 2005) and indicated that Caucasian adolescents of both genders were taller, heavier and had a higher %BF and FFM than the black adolescents.

Regarding gender the results indicate that girls of both ethnicities were significantly heavier, had a higher BMI and %BF than the boys, but the boys had a significantly higher FFM than girls of both ethnicities, supporting previous studies (DeLany *et al.*, 2002; DeLany *et al.*, 2004; DeLany *et al.*, 2006). In the present study boys of both ethnicities



had a higher RMR than the girls. These results are congruent with previous findings (Kaplan *et al.*, 1996; Morrison *et al.*, 1996; Sun *et al.*, 2001; Yanovski, 2001; Bandini *et al.*, 2002; DeLany *et al.*, 2004; DeLany *et al.*, 2006).

When comparing ethnicity it was found that Caucasian boys had a significantly ( $p < 0.05$ ) higher RMR than black boys, which was similar to the results of previous studies (Kaplan *et al.*, 1996; DeLany *et al.*, 2002; DeLany *et al.*, 2004). Regarding body composition the Caucasian boys had significantly higher BMI and FFM values than the black boys. Kaplan *et al.* (1996) found that ethnic background was an independent determinant of RMR and when combined with FFM, accounted for 70% of the variance in RMR. With regard to girls in this study, Caucasian girls had significantly higher BMI, WHTR and RMR than the black girls. These differences between Caucasian and black girls are expected since previous studies reported a lower RMR in African American girls than in their Caucasian counterparts (Kaplan *et al.*, 1996; Morrison *et al.*, 1996; Wong, Butte, Ellis & Et, 1999; Bandini *et al.*, 2002; DeLany *et al.*, 2006). The results are consistent with the notion that a lower RMR could be related to the higher prevalence of obesity in black vs. Caucasian girls. The lower RMR in African Americans could be ascribed to differences in the composition of the body's FFM compartment (Kaplan *et al.*, 1996, Gallagher, 1998; Gallagher *et al.*, 2006).

For both ethnicities the overweight group of adolescents had the highest RMR, confirming that RMR is mostly found to be higher in obese than in non-obese children when absolute values (kJ/d) are compared (Epstein, Wing & Cluss, 1989; Bandini, Schoeller & Dietz, 1990; Maffeis, Maffeis, Pinelli & Schutz, 1995; Molnar & Schutz, 1997; Treuth, Figueroa-Colon, Hunter, Weinsier, Butte & Goran, 1998; Schultz, Rueda-Maza, Zaffanello & Maffeis, 1999; DeLany *et al.*, 2002; Tounian *et al.*, 2003; Butte *et al.*, 2007).

In all BMI categories (underweight, normal weight and overweight) the Caucasian adolescents had a higher FFM than the black adolescents, with the underweight black adolescents having the lowest FFM and the overweight Caucasian adolescents having the highest FFM. FFM (organ, skeletal and bone mass) is the main contributor of energy consumption and total-body FFM is commonly used as a surrogate for metabolically active tissue (Gallagher *et al.*, 2006). African Americans have a smaller mass of the most

metabolically active organs and, therefore, a lower proportion of FFM as high-metabolic-rate (HMR) organs (sum of liver, heart, spleen, kidneys and brain), than Caucasians (Gallagher, 1998; Gallagher *et al.*, 2006). The reason for the persistent ethnic group differences in RMR among children and adolescents is not clear, but the results suggest that there is a strong relationship between the amount of FFM and RMR. The results show that black girls have the lowest FFM and RMR and Caucasian boys had the highest FFM and RMR. Ethnic differences in RMR could be explained by differences in body size and body mass (Morrison *et al.*, 1996). Morrison *et al.* (1996) and Tremblay (2010) agree that lean body mass (LBM) is the most important body composition factor for explaining the variance in RMR.

In agreement with the previous studies, FFM was found to be higher in obese/overweight than in normal weight children (Bandini *et al.*, 1990; Maffeis *et al.*, 1995; Treuth *et al.*, 1998; DeLany *et al.*, 2002; Tounian *et al.*, 2003; DeLany *et al.*, 2004; Butte *et al.*, 2007). Contrary to our findings a study by Stensel *et al.* (2001) reported that FFM did not differ significantly between obese and normal weight boys. Regarding the BMI groups, the black adolescents had lower values of all body composition parameters than the Caucasian adolescents for all BMI categories. The overweight adolescents of both ethnicities had the highest FFM and RMR, which is supported by Epstein *et al.* (1989); Bandini *et al.* (1990) Maffeis *et al.* (1993); Maffeis *et al.* (1995); Molnar & Schutz (1997); Treuth *et al.* (1998); Schutz *et al.* (1999); DeLany *et al.* (2002); Tounian *et al.* (2003) and Butte *et al.* (2007) that found that RMR is mostly found to be higher in obese than in non-obese children when absolute values (kJ/d) are compared. Previous cross-sectional studies examining RMR in obese and non-obese children have, however, reported discrepant findings. After control for FFM, most studies reported that RMR did not differ significantly between obese and non-obese children, although some studies still reported higher RMR values in the obese children (Stensel *et al.*, 2001; Butte *et al.*, 2007). Kaplan *et al.* (1996), however, found that black children have a significantly lower RMR than Caucasian children, but indicated a difference between the groups as well, where black obese children had a higher RMR compared with black non-obese children, but still significantly lower than the obese and non-obese Caucasian children who had higher RMR.

Additionally, the results showed a high non-significant negative relationship between RMR and FFM, and RMR and BMI in the overweight group. These observed relationships in the overweight group, though not significant, may be explained by the low energy expenditure in overweight children (Butte *et al.*, 2007). After adjusting for gender and ethnicity a high non-significant negative relationship between RMR and FFM in the overweight group was observed. The non-significant negative relationship between RMR and FFM observed in the study, though not significant, are similar to the findings on a freely-living population of Giessen (Neuhäuser-Berthold *et al.*, 2000).

The present study has several limitations which should be noted when interpreting this study. First, the data set comprised of limited numbers of Caucasian adolescents. Thus, further assessment of a more balanced data set to confirm our results would be appropriate, although the numbers in our study are consistent with national statistics on ethnic group numbers. Secondly, the study did not look at the development of maturation (given the fact that the participants were derived from one age group), which may one way or the other have contributed some information on the differences on body composition and RMR. Third, the cross-sectional design of the study might affect the conclusions made as compared to the longitudinal design which often have more advantages in providing conclusions particularly in epidemiological studies. Nevertheless, the most interesting aspect about the PAHL-study is that it will continue to follow-up these adolescents over a period of time as some of the conclusions made will further be cleared. Lastly, the study was only based on convenience participants around Tlokwe municipality which restricts generalizations that might be made for all adolescents in Tlokwe municipality and South Africa as a whole.

In conclusion, the present cross-sectional results revealed significant differences in body composition and RMR between black and Caucasian adolescents of the Tlokwe municipality. The study further shows the existence of both underweight and overweight in the black and Caucasian adolescents. In addition the study found that Caucasian adolescents of both genders have a high RMR and FFM compared to their counterpart black adolescents. It was evident from the results that FFM, though not significant, was highly associated with RMR in the overweight adolescents. Whether the observed ethnic

differences in RMR predict future weight gain and obesity awaits the results of longitudinal analyses.

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**Disclaimer:** Any opinion, findings and conclusions or recommendations expressed in this material are those of the author(s) and therefore the NRF does not accept any liability in regard thereto.

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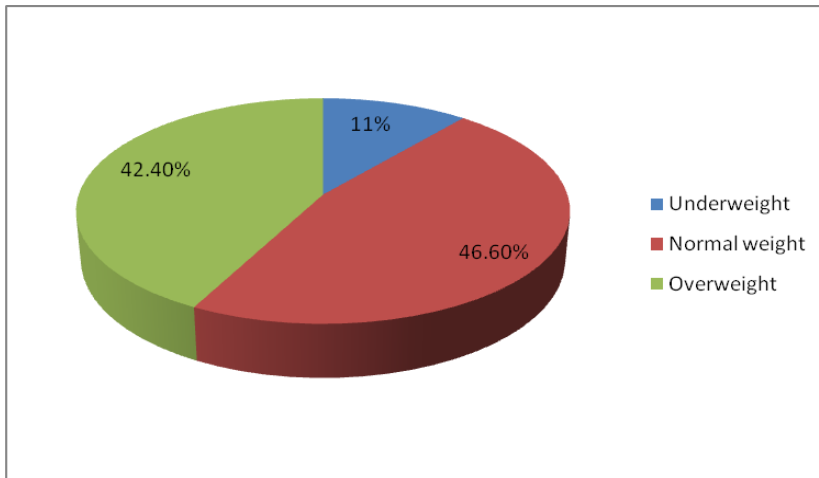
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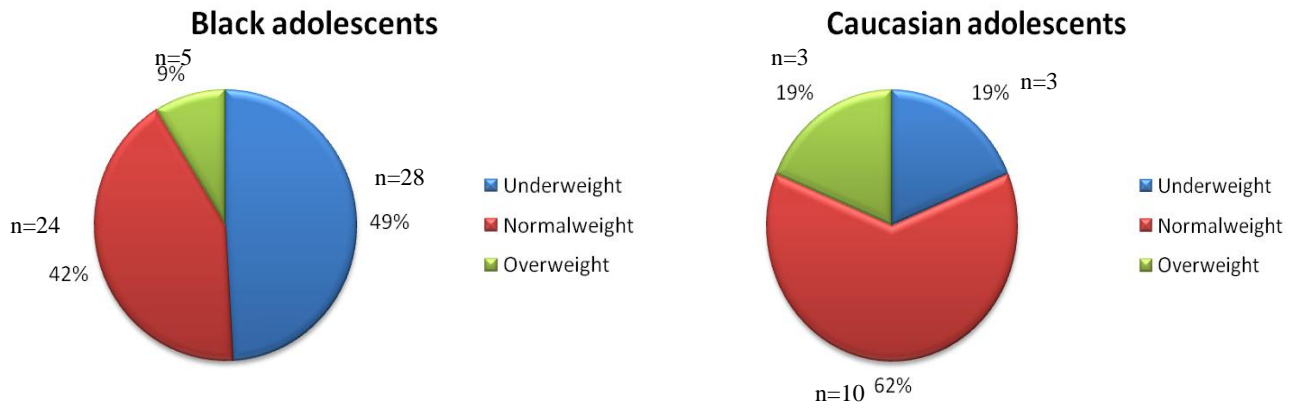
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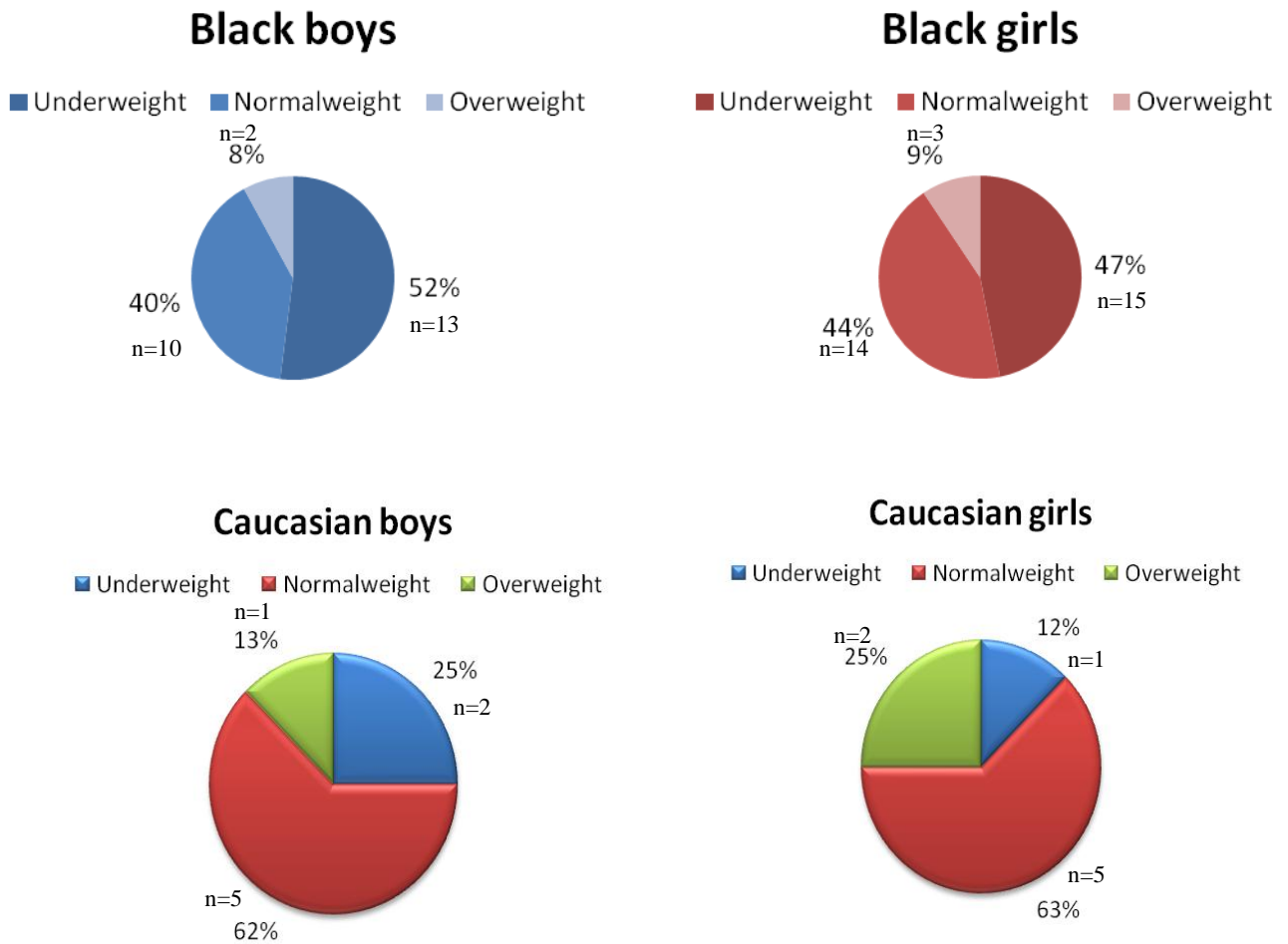
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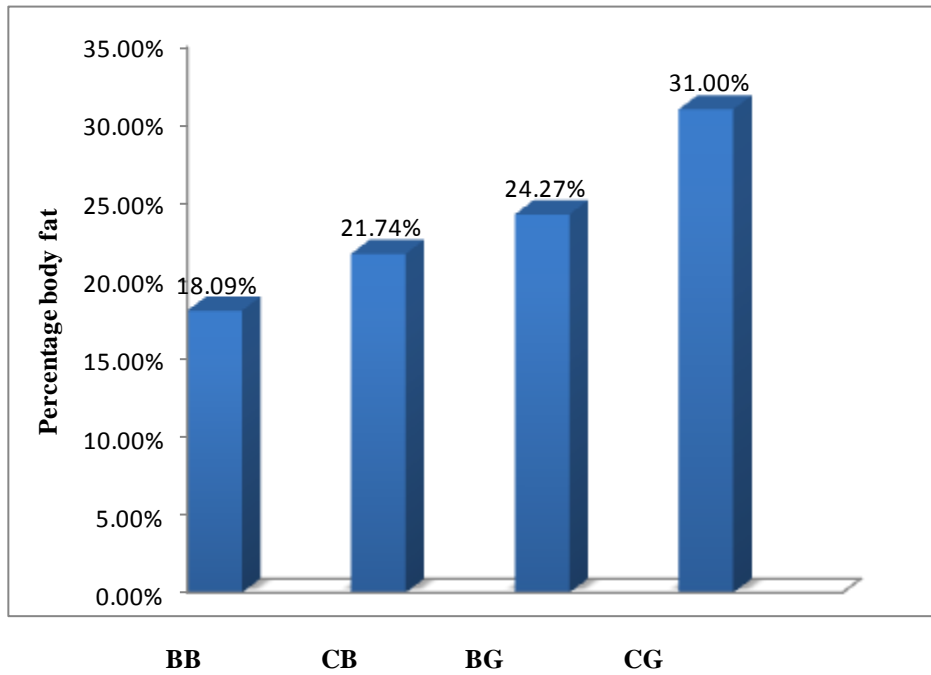
**Figure 1: Percentage of adolescents classified according to the BMI categories of Cole *et al.* (2000) and Cole *et al.* (2007) for the total group.**



**Figure 2: Percentage adolescents classified according to BMI categories of Cole *et al.* (2000) and Cole *et al.* (2007) for black and Caucasian adolescents separately.**



**Figure 3: Percentage of adolescents classified according to the BMI categories by gender and ethnicity (Cole *et al.*, 2000; Cole *et al.*, 2007)**



**Figure 4: Average percentage body fat of the total group for ethnicity and gender**  
**BB = Black Boys; CB = Caucasian Boys; BG = Black Girls; CG = Caucasian Girls**



**Table 1: Descriptive characteristics of the total group for body composition and RMR (n=73)**

Parameters	Black (n = 57)		Caucasian (n = 16)		Difference between groups
	Mean	SD	Mean	SD	
Body mass(kg)	48.01	11.27	64.05	18.12	0.00
Stature (cm)	154.99	7.46	165.94	8.90	0.00
BMI (kg/m <sup>2</sup> )	19.87	3.84	23.21	6.32	0.01
WHTR	0.42	0.42	0.45	0.09	0.05
% BF	21.56	9.05	26.38	10.43	0.07
FFM (kg)	26.44	7.88	37.67	12.79	0.004
RMR (kcal/day)	1253.75	287.09	1590.25	454.86	0.001

BM = body mass; BMI = body mass index; WHTR = waist-to-height ratio; % BF = percentage body fat (triceps and subscapular); FFM = fat-free mass; RMR = resting metabolic rate; SD = Standard Deviation

**Table 2: Descriptive characteristics of RMR and body composition for boys and girls by ethnicity**

Parameters	Boys				Girls			
	n	Mean	SD	P-value of difference	n	Mean	SD	P-value of difference
BM (kg)								
Black	25	47.86	11.18	0.01	32	48.12	11.53	0.002
Caucasian	8	62.46	18.72		8	65.64	18.63	
Stature (cm)								
Black	25	155.73	7.75	0.001	32	154.42	7.30	0.003
Caucasian	8	168.91	11.22		8	162.98	4.89	
BMI(kg/m <sup>2</sup> )								
Black	25	19.59	3.67	0.22	32	20.09	4.01	0.02
Caucasian	8	21.83	6.37		8	24.59	6.38	
WHTR								
Black	24	0.41	0.05	0.21	32	0.42	0.04	0.15
Caucasian	8	0.42	0.09		8	0.45	0.09	
% BF								
Black	25	18.09	8.12	0.31	32	24.27	8.92	0.06
Caucasian	8	21.74	10.64		8	31.02	8.41	
FFM (kg)								
Black	25	29.77	8.69	0.004	32	23.84	6.14	0.001
Caucasian	8	40.72	12.48		8	34.62	13.16	
RMR(kcal/day)								
Black	25	1288.36	339.39	0.01	32	1226.72	240.82	0.02
Caucasian	8	1713.38	560.16		8	1467.13	308.09	

BM = body mass; BMI = body mass index; WHTR = waist-to-height ratio; % BF = percentage body fat (triceps and subscapular); FFM = fat-free mass; RMR = resting metabolic rate; SD = Standard Deviation.

**Table 3: BMI categories for underweight, normal weight and overweight black and Caucasian adolescents (Cole *et al.*, 2000; Cole *et al.*, 2007)**

Parameters	Underweight			Normal weight			Overweight/Obese		
	Black (n = 28)			Black (n = 24)			Black (n = 5)		
	Caucasian (n = 3)			Caucasian (n = 10)			Caucasian (n = 3)		
	Mean	SD	P-value of difference	Mean	SD	P-value of difference	Mean	SD	P-value of difference
<b>BM (kg)</b>									
<b>Black</b>	40.61	5.29	0.13	51.5	5.49	0.001	72.64	14.21	0.04
<b>Caucasian</b>	45.57	4.56		60.11	8.40		95.67	5.78	
<b>Stature(cm)</b>									
<b>Black</b>	153.46	8.705	0.21	156.26	5.84	0.000	157.48	6.18	0.12
<b>Caucasian</b>	160.13	5.1695		168.08	10.36		164.63	3.05	
<b>BMI (kg/m<sup>2</sup>)</b>									
<b>Black</b>	17.18	0.9643	0.35	21.09	1.90	0.838	29.09	3.70	0.04
<b>Caucasian</b>	17.73	0.6701		21.23	1.78		35.28	1.43	
<b>WHTR</b>									
<b>Black</b>	0.39	0.0195	0.40	0.42	0.03	0.890	0.53	0.05	0.05
<b>Caucasian</b>	0.38	0.0120		0.42	0.04		0.61	0.46	
<b>% BF</b>									
<b>Black</b>	16.97	4.32	0.36	23.15	7.89	0.689	39.59	9.67	0.96
<b>Caucasian</b>	19.35	3.40		24.42	9.56		39.92	4.99	
<b>FFM(kg)</b>									
<b>Black</b>	23.63	5.81	0.46	28.35	8.67	0.03	33.05	8.78	0.01
<b>Caucasian</b>	26.21	4.75		35.68	9.34		55.74	10.24	
<b>RMR(kcal/day)</b>									
<b>Black</b>	1166.57	200.98	0.66	1320.17	346.76	0.034	1423.2	272.57	0.07
<b>Caucasian</b>	1108.33	335.08		1619.0	383.87		1976.33	447.50	

BM = body mass; BMI = body mass index; WHTR = waist-to-height ratio; % BF = percentage body fat (triceps and subscapular); FFM = fat-free mass; RMR = resting metabolic rate; SD = Standard Deviation; Underweight = BMI < 18.5; Normal weight = BMI 18.5-25; Overweight = BMI > 25; Obese = BMI >30; Obese - WHTR > 0.485 for boys; WHTR > 0.475 for girls.

**Table 4: Pearson product moment correlation coefficients for the associations of RMR with body composition parameters for underweight, normal and overweight adolescents (Cole *et al.*, 2000; Cole *et al.*, 2007)**

	Underweight		Normal weight		Overweight	
	RMR (kcal/day)		RMR (kcal/day)		RMR (kcal/day)	
	<b>r</b>	<b>p</b>	<b>r</b>	<b>p</b>	<b>r</b>	<b>p</b>
<b>BMI (kg/m<sup>2</sup>)</b>	0.17	0.35	0.04	0.81	0.58	0.13
<b>FFM (kg)</b>	0.03	0.84	0.38	0.03	0.608	0.11
<b>%BF</b>	-0.02	0.91	-0.01	0.92	0.00	0.99

Underweight = BMI < 18.5; Normal weight = BMI 18.5-25; Overweight = BMI > 25; RMR = resting metabolic rate (kcal/day); BMI = body mass index; FFM = fat-free mass; % BF = percentage body fat.

**Table 5: Correlation coefficients for the associations of RMR adjusted for gender and ethnicity with body composition parameters for underweight, normal and overweight adolescents according to Cole *et al.* (2000) and Cole *et al.* (2007).**

	Underweight		Normal weight		Overweight	
	RMR (kcal/day)		RMR (kcal/day)		RMR (kcal/day)	
	<b>r</b>	<b>p</b>	<b>r</b>	<b>p</b>	<b>r</b>	<b>p</b>
<b>BMI (kg/m<sup>2</sup>)</b>	0.16	0.39	0.069	0.70	0.29	0.57
<b>FFM (kg)</b>	0.12	0.52	0.10	0.58	-0.367	0.47
<b>%BF</b>	-0.13	0.48	0.13	0.47	0.60	0.20

Underweight = BMI < 18.5; Normal weight = BMI 18.5-25; Overweight = BMI > 25; RMR = resting metabolic rate (kcal/day); BMI = body mass index; FFM = fat-free mass; % BF = percentage body fat.

## Chapter 4



### 4.1 Summary

### 4.2 Conclusions

### 4.3 Recommendations and Limitations

### 4.4 Future Research

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#### 4.1 Summary

From the current literature available it is clear that there is an increase in adolescent obesity with the health related consequences of obesity in developed countries, as well as in many developing countries, including South Africa. The literature further indicated ethnic and gender differences in body composition (BC) with African American adolescents having a lower fat free mass (FFM) than Caucasian adolescents and boys of both ethnicities having a higher FFM and lower fat mass (FM) than girls. Limited research is available regarding ethnic differences in body composition in South African adolescents. Body composition of South African children and adolescents are relevant because of both malnutrition and obesity being present in the South African population.

Body composition is often related to the resting metabolic rate (RMR) of the individual. Caucasians are documented to have higher RMR than African Americans for both genders with boys of both ethnicities having higher RMR than girls, but the data for obese children and adolescents with regards to RMR are limited. The literature reports a strong relationship between RMR and FFM in the general healthy population. Ethnic differences in RMR could be explained by differences in body composition. FFM was found to be the most important body composition factor for explaining the variance in RMR. RMR is however also influenced by fat mass (FM), as it is considered metabolically active by some researchers. The literature also suggests that a low RMR

could be a pre-disposing factor for long-term weight gain and obesity, but the evidence is not very strong. If future research confirms a lower RMR in African American than in Caucasian children during pubertal development, the lower metabolism could be related to the increased prevalence of obesity in the African American population. In South Africa, in spite of the increasing prevalence of adolescent obesity, limited research has been published with regards to BC and RMR in adolescents living within the Tlokwe municipality of the North West Province.

A lack of information in the literature leads to the empirical investigation in RMR and body composition of adolescents. The aim of the study was to determine body composition and resting metabolic rate of black and Caucasian adolescents, and to determine the relationship between the body composition characteristics body mass index (BMI), percentage body fat(%BF), fat free mass(FFM) and RMR in the adolescents attending schools within the Tlokwe municipality: the PAHL-Study.

The results of the study are presented in an article format (Chapter 3) and prepared according to the guidelines of the *African Journal for Physical, Health Education, Recreation & Dance* for submission.

## 4.2 Conclusions

The conclusions drawn from this research are reported in accordance with the hypothesis set for this study (Chapter 1).

**Hypothesis 1:** States that ethnic differences in BC and RMR exist, with Caucasian adolescents having a higher FFM and RMR than the black 14 year old adolescents of the North West Province, South Africa.

**Conclusion 1:** The Caucasian adolescents were significantly ( $p < 0.05$ ) taller, heavier and had a higher %BF, WHTR, FFM and RMR than the black adolescents of both genders. Boys of both ethnicities had a higher RMR than the girls, with black girls having the lowest RMR. The RMR of black adolescents were lower regardless of whether they were

obese or non-obese. Both underweight and overweight/obesity were present in both ethnic groups and genders emphasizing the double burden of disease prevalent in South Africa. It can, therefore, be concluded that ethnic differences in BC and RMR, even though not significant exist, with black adolescents having a lower FFM and RMR than Caucasian adolescents. *Hypothesis 1 is therefore accepted.*

**Hypothesis 2:** A positive relationship is present between body composition characteristics body mass index (BMI), fat free mass (FFM), percentage body fat (%BF) and RMR related to obesity in adolescents of the North West Province, in South Africa.

**Conclusion 2:** Correlation coefficients adjusted for gender and ethnicity indicated a positive relationship between RMR and BMI, and RMR and FFM for the underweight and normal weight group. In the overweight group RMR was positively associated with BMI and %BF. A high non-significant negative relationship between RMR and FFM was observed in the overweight group. The overweight/obese group of both ethnicities had a higher FFM and RMR than the normal and underweight group. It was evident from the results that FFM, though not significant, was highly associated with RMR in the overweight adolescents. *Hypothesis 2 is, therefore, partly accepted.*

The Caucasian adolescents were taller, heavier and had a higher %BF, FFM and RMR than the black adolescents. As the Caucasians were physically larger than the black adolescents at 14 years of age, it seems that the Caucasian adolescents reached puberty before the black adolescents and were more developed than the black adolescents who were physically smaller. Adolescence is a critical period in which marked changes in physical size, shape and body composition occur, including weight gain, a yearly height velocity and an increase in fat free mass. As the Caucasian adolescents were more mature, they had a higher FFM and %BF than the black adolescents.

RMR is associated with FFM and as Caucasian adolescents have a higher FFM, it is expected that RMR will be higher in the Caucasian adolescents. Fat free mass (organ, skeletal and bone mass) is the main contributor of energy consumption and total-body



FFM is commonly used as a surrogate for metabolically active tissue. Therefore, a possible explanation for the higher RMR in Caucasian adolescents is the larger quantity of metabolically active FFM than in black adolescents. Studies have shown, that bone mineral mass is greater in black children and adolescents, than in Caucasian children and adolescents. Because bone has a low metabolic activity, a greater bone mineral mass may be a cause for the lower RMR in black adolescents.

It should, however, be taken into consideration that lifestyle factors (dietary habits and nutrition) can also influence body composition. Most of the Caucasian adolescents are from high socio-economic areas, with the largest percentage of the group being normal weight. They, therefore, have corresponding high FFM and %BF values. Most of the black adolescents come from low socio-economic areas where underweight and under nutrition is more prevalent, thus a possible reason for the corresponding lower FFM and %BF seen in the black adolescents. The higher %BF reported in the Caucasian adolescents could also contribute to the higher RMR. Fat mass (FM) secretes a component, such as leptin, in proportion to FM, which in turn increases RMR and could be a possible explanation for the higher RMR in Caucasian adolescents.

The higher RMR in Caucasian adolescents, therefore, is possibly due to ethnic differences in BC, with Caucasian adolescents having a higher FFM and %BF, as well as Caucasians reaching puberty prior to black adolescents.

Boys of both ethnicities had a higher FFM and RMR and lower %BF than the girls. The preferential deposition of body fat in girls and FFM in boys are the defining body composition changes during the adolescent years. The differences in body composition as a result of maturation are apparent as girls gain more FM than boys, whereas boys gain more FFM, especially skeletal muscle. These alterations are expected to induce changes in metabolic rate and energy requirements of adolescents as RMR is closely related to FFM. The higher RMR observed in boys could, therefore, be ascribed to the higher FFM (especially the increase in skeletal muscle which is metabolically active) in boys. Girls reach puberty before boys and have a smaller increase in the amount of FFM which is metabolically active and a larger increase in the amount of FM which is less metabolically active, possibly resulting in the lower RMR observed in girls.

In conclusion, ethnic and gender differences in body composition and RMR exist in these adolescents. The strong relationship between parameters of BC and RMR suggest that fundamental differences in BC (mainly the amount of FFM and FM) could be responsible for the ethnic differences in RMR. The lower FFM and RMR, therefore, seen in black

adolescent girls could be a possible reason for the increase in obesity as observed in black South African girls and woman.

### **4.3 Recommendations and Limitations**

The present study has several limitations which should be noted when interpreting this study and which could be overcome in future research. The limitations and their subsequent recommendations include the following:

- Firstly, the data set comprised of limited numbers of Caucasian adolescents. Thus, further assessment of a more balanced data set to confirm our results would be appropriate, although the numbers in our study are consistent with national statistics on ethnic group numbers.
- Secondly, the study did not look at the development of maturation (given the fact that the participants were derived from one age group), which may one way or the other have contributed to the differences in body composition and RMR. As such it is recommended that measurements of maturation must be taken into consideration in the future.
- Lastly, the cross-sectional design of the study might have affected the conclusions made. As such future studies must investigate the body composition and RMR over a period of time so as to determine their longitudinal associations.

### **4.4 Future research**

This study was a cross-sectional design. In order to obtain a clear understanding of the relationship between RMR and body composition in the future, the following suggestions can be made:

- collect similar data in a longitudinal research design, with a larger recruited sample size
- determine the role of birth weight in relation to resting metabolic rate and body composition later in life
- consider the influence of maturation level on body composition and RMR with verification of maturation with blood analyses
- perform exercise intervention studies to determine if changes in fitness level will also influence resting metabolic rate

- complete questionnaires on contributing factors like socio-economic status, history of physical activity, dietary and lifestyle factors that can influence BC and RMR
- determine the other components of energy expenditure, energy of physical activity, and the thermic effect of food, as to accurately discuss the contribution of a lower RMR to the development of obesity.

It is, however, suggested that strategic intervention programmes be implemented focusing on the prevention of obesity and excess fat gain in all adolescents. It is possible that the lower RMR and FFM in black adolescent girls could be a risk factor for the subsequent development of obesity. It is, therefore, recommended that black adolescent girls by default be an important focus of public health, with the focus on early intervention strategies to prevent excessive body mass and fat gain. Biokineticists are trained health-care providers in the field of wellness, healthy lifestyle and physical activity. They could effectively assist in the prevention of obesity with an exercise programme that leads to changes in body composition with an increase in FFM and decrease in FM, thereby, possibly increasing RMR and decreasing the risk for obesity.

# Appendices



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- Appendix A: Guidelines for authors
  - Appendix B: Letter to the District Operational Director
  - Appendix C: Informed consent form
  - Appendix D: Anthropometry form
- 



## **APPENDIX A**

### **GUIDELINES FOR AUTHORS**

The African Journal for Physical, Health Education, Recreation and Dance (AJPHERD) is a peer-reviewed journal established to:

- i) Provide a forum for physical educators, health educators, specialists in human movement studies and dance, as well as other sport-related professionals in Africa, the opportunity to report their research findings based on African settings and experiences, and also to exchange ideas among themselves,
- ii) Afford the professionals and other interested individuals in these disciplines the opportunity to learn more about the practice of the disciplines in different parts of the continent,
- iii) Create an awareness in the rest of the world about the professional practice in the disciplines in Africa.

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Three copies of original manuscript and all correspondence should be addressed to the Editor-In-Chief:

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## **PREPARATION OF MANUSCRIPT**

Manuscripts should be type written in fluent English (using 12-point Times New Roman font and 1½ line-spacing) on one side of white A4-sized paper justified fully with 3cm margin on all sides. *Guidelines for Authors* 317. In preparing manuscripts, MS-Word, Office 98 or Office 2000 for Windows should be used. Length of manuscripts should not normally exceed 12 printed pages (including tables, figures, references, etc.). For articles exceeding 10 typed pages US\$ 10.0 is charged per every extra page. Longer manuscripts may be accepted for publication as supplements or special research reviews. Authors will be requested to pay a publication charge of US\$ 350.0 to defray the very high cost of publication. The pages of manuscripts must be numbered sequentially beginning with the title page. The presentation format should be consistent with the guidelines in the publication format of the American Psychological Association (APA) (4th edition).

### Title page:

The title page of the manuscript should contain the following information:

Concise and informative title.

Author(s') name(s) with first and middle initials. Authors' highest qualifications and main area of research specialisation should be provided.

Author(s') institutional addresses, including telephone and fax numbers.

Corresponding author's contact details, including e-mail address.

A short running title of not more than 6 words.

### Abstract

An abstract of 200-250 words is required with up to a maximum of 5 words provided below the abstract. Abstract must be typed on a separate page using single line spacing, with the purpose of the study, methods, major results and conclusions concisely presented. Abbreviations should either be defined or excluded.

### Text

Text should carry the following designated headings: Introduction, materials and methods, results, discussion, acknowledgement, references and appendices (if appropriate).

### ***Introduction***

The introduction should start on a new page and in addition to comprehensively giving the background of the study should clearly state the problem and purpose of the study. Authors should cite relevant references to support the basis of the study. A concise but informative and critical literature review is required.

### ***Materials and Methods***

This section should provide sufficient and relevant information regarding study participants, instrumentation, research design, validity and reliability estimates, data collection procedures, statistical methods and data analysis techniques used. Qualitative research techniques are also acceptable.

### Results

Findings should be presented precisely and clearly. Tables and figures must be presented separately or at the end of the manuscript and their appropriate locations in the text indicated. The results section should not contain materials that are appropriate for presentation under the discussion section. Formulas, units and quantities should be expressed in the *systeme* 318 *Guidelines for Authors*

*internationale (SI)* units. Colour printing of figures and tables is expensive and could be done upon request authors' expense.

#### Discussion

The discussion section should reflect only important aspects of the study and its major conclusions. Information presented in the results section should not be repeated under the discussion. Relevant references should be cited in order to justify the findings of the study. Overall, the discussion should be critical and tactfully written.

#### References

The American Psychological Association (APA) format should be used for referencing. Only references cited in the text should be alphabetically listed in the reference section at the end of the article. References should not be numbered either in the text or in the reference list.

Authors are advised to consider the following examples in referencing:

Examples of citations in body of the text:-

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In compiling the reference list at the end of the text the following examples for journal references, chapter from a book, book publication and electronic citations should be considered:

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

For multiple authors: Kemper, G.A., McPherson, A.B., Toledo, I. & Abdullah, I.I. (1996). Kinematic analysis of forehand smash in badminton. *Science of Racket Sports*, 24(2), 99-112.

Examples of book references: *Guidelines for Authors* 319

Book references should specify the surname and initials of the author(s), year of publication of the book, title, edition, page numbers written in brackets, city where book was published and name of publishers. Chapter references should include the name(s) of the editor(s) and other specific information provided in the third example below:

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

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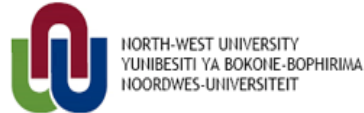
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## **APPENDIX B**





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25 January 2010

The District Operational Director

Department of Education  
North West Province  
Potchefstroom

### **REQUEST TO CONDUCT RESEARCH WITHIN YOUR DISTRICT**

Dear Sir,

We the researcher from the School of Biokinetics, 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 behavioral 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 behaviors 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 behaviors 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 behavior 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. TlokweHigh School
- 1.3. ResolofetseHigh School
- 1.4. BotokwaHigh School
- 1.5. PotchefstroomHigh School for Boys
- 1.6. PotchefstroomHigh School for Girls
- 1.7. Hoer Volkskool Potchefstroom
- 1.8. PotchefstroomGimnasiumSchool

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. Anthropometric measurements (i.e. body height; weight; skinfolds thickness (triceps, subscapular and calf skinfolds), and waist and hip circumferences)
- 4.3. Maturation (Tanner questionnaire)
- 4.4. Blood pressure measurement (mercury sphygmomanometer)
- 4.5. Physical activity questionnaire
- 4.6. ActiHeart (heart rate recorder with an integrated omnidirectional accelerometer. 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):

<b>Month and week</b>	<b>Duration</b>
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.

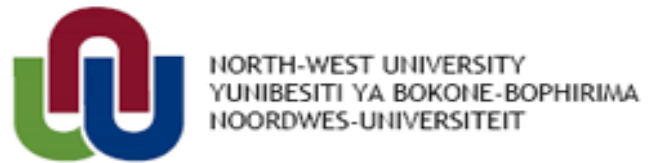
Yours sincerely,

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 C



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  
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 behavioral 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 be 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 DrHanlie 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 MsHannekie 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 colleting 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. MakamaAndriesMonyeki  
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 MsHannekie 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)

**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 MsHannekie 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 D**

**PAHLS Project - Anthropometry Proforma**



Subject number:

Name: ..... Sport: .....  
                                 Surname                                first names

Date of Birth:     
                                 Day                        Month                        Year

Test Date:     
   Year                        Day                        Month

Box height: .....

Gender: M  F

	<i><b>ID</b></i>	<i><b>Site</b></i>	<i><b>Trail 1</b></i>	<i><b>Trail 2</b></i>	<i><b>Trail 3</b></i>	<i><b>Mean/ Median</b></i>
<b>Basic</b>	1	Body mass				
	2	Stature				
	3	Sitting height				
	4	Armspan				

<b>Skinfolds</b>	5a	Triceps : R				
<b>(SF)</b>	5b	Triceps : L				
<b>(mm)</b>	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				

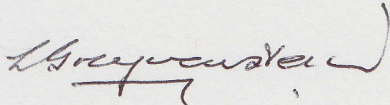
<b>Girths</b>	12	Head				
<b>GR</b>	13a	Arm (relaxed) : R				
<b>(cm)</b>	13b	Arm (relaxed) : L				

	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				

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

This is to certify that the language editing of this dissertation by Ms V Hoops was done by Prof L A Greyvenstein.

Prof L A Greyvenstein was a member of the South African Translators' Institute, membership number: 1001691. She completed her primary, secondary and tertiary education, including a doctoral thesis, in English. She has done the English language editing of many proposals, dissertations, theses and scientific articles.



Lesley Ann Greyvenstein (Prof)

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